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SOME PROBLEMS OF ENERGY SECURITY IN THE CONTEXT OF WIDESPREAD USE OF RES

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ABSTRACT: The use (possibility of using) of renewable energy sources in Azerbaijan is considered in the paper. It is shown that in connection with the environmental problems associated with fuel combustion, as well as in connection with the depletion of fossil fuel reserves, it is advisable to use environmentally friendly and inexhaustible types of renewable energy sources.
KEYWORDS: renewable energy sources, installed capacity, solar energy, wind energy, power plant, power generation

НЕКОТОРЫЕ ПРОБЛЕМЫ ЭНЕРГЕТИЧЕСКОЙ БЕЗОПАСНОСТИ В УСЛОВИЯХ ШИРОКОГО ИСПОЛЬЗОВАНИЯ ВИЭ

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АННОТАЦИЯ: В статье рассматривается использование (возможность использования) возобновляемых источников энергии в Азербайджане. Показано, что в связи с экологическими проблемами, связанными с сжиганием топлива, а также в связи с истощением запасов ископаемого топлива целесообразно использовать экологически чистые и неисчерпаемые виды возобновляемых источников энергии.
КЛЮЧЕВЫЕ СЛОВА: возобновляемые источники энергии, установленная мощность, солнечная энергия, энергия ветра, электростанция, выработка электроэнергии.

INTRODUCTİON

One of the most important problems of the modern world is the problem of climate change. The warming of the climate observed in recent decades is associated with an increase in the concentration of six main greenhouse gases in the atmosphere, and first of all CO2, 40% of their emission occurs during the combustion of fossil fuel.

The Kyoto Protocol, adopted in 1997, was the first document in accordance with which governments assumed legal obligations to limit greenhouse gas emissions.

Instead of the Kyoto Protocol, during the Paris Climate Conference in 2015 the Paris Agreement was adopted, which aimed to “intensify implementation” of the UN Framework Convention on

Climate Change, in particular, to restrain the growth in global average temperature and make efforts for the limitation of the temperature rise to 1 .5°C.

The Kyoto Protocol adopted in 1997 and the Paris Agreement adopted in 2015 did not bring tangible changes towards stabilization of the Earth's climate. In September 2021, the UN Climate Conference COP26 was held in Glasgow with the participation of more than 100 heads of states and governments. The purpose of this conference was to join efforts of countries in the fight against further climate change on the planet.

To stop climate change, it is necessary to reduce the consumption of carbon-rich fossil fuel using renewable energy sources (RES).

The declining costs of the capex and opex generation of renewable energy (capital) generation, which opens up vast opportunities for the reconstruction of the electricity sector, play an important role in ensuring the energy security of the energy produced by these technologies [1,2]. Wind and solar photovoltaic (PF) plants will provide more than half of the additional electricity generation by 2040 and almost all of the growth in terms of fulfilling the UN climate change commitments under the UN Convention on Climate Change (TC 21, Paris Agreement). Governments and regulators will have to act quickly to keep up with the pace of technological change and the growing need for flexible operation of energy systems. The rapid development of the market of energy accumulation (storage) technologies, the interface between electric vehicles and the network, the confidentiality of data, etc. Such issues are becoming a potential source of risk for consumers and national power systems [3,4].

USE OF RES IN THE WORLD

Sustainable development and use of renewable energy sources is observed in many countries of the world.

In 2020 the 27 EU countries for the first time received most of the produced electric power from renewable sources. The share of coal, gas and oil fell to 37%, while wind, solar, hydropower and biomass increased production by 10%, accounting for 38% of total generation in EU. According to the forecasts of the European Association for Renewable Energy Sources, by 2040 about 50% of the world's electric power production will be based on RES.

According to the International Renewable Energy Agency (IRENA), the installed capacity of renewable energy sources in 2020 was 2,799,094 MW, thus the share of renewable energy sources in the total installed capacity was 36.6% (Figure 1) [5].

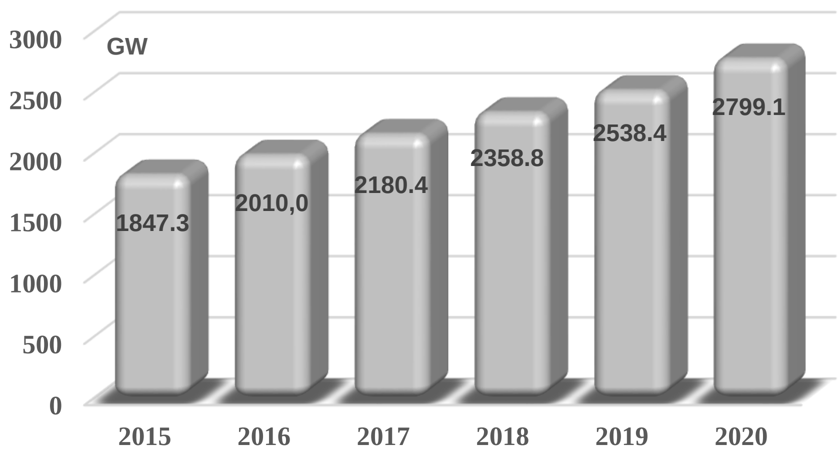

Figure 1. Installed capacity of RES according to IRENA

Despite the economic downturn due to COVID-19, the annual growth of renewable energy in 2020 was 260 GWh, which is 50% more than in 2019. By 2030, the share of renewable energy sources in the EU energy balance will increase from 32% to 60%. Figure 2 shows the dynamics of the growth of renewable energy sources in the world. As you can see from the graph, in 2020 the annual growth was 10.3%.

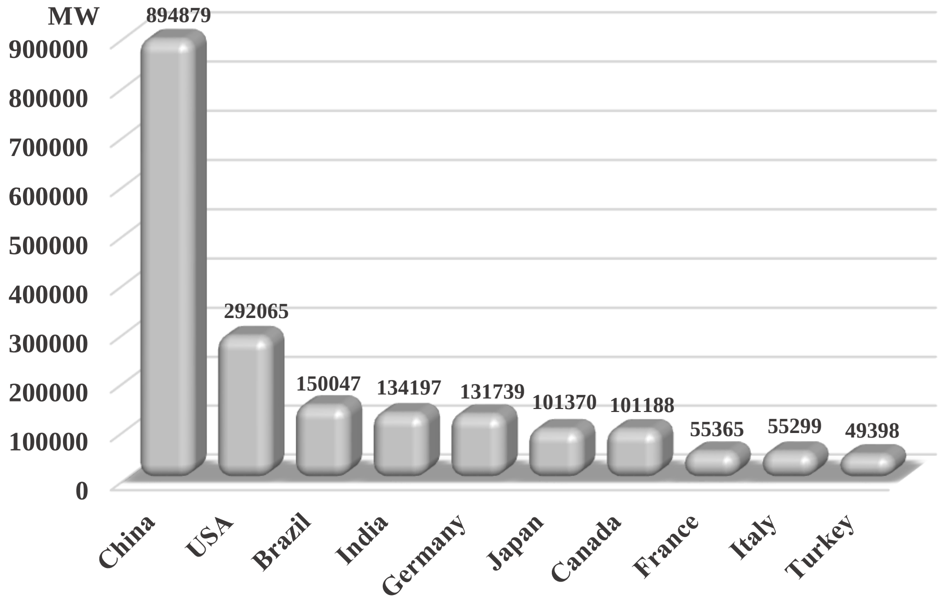

Figure 2. Dynamics of RES growth in the world for 2020

Despite the economic crisis, with wind and solar energy growing by 9% and 15% in 2020, renewable energy sources (RES) have become the leaders in power generation.

Last year, renewable energy provided 19% of the electrification of the EU (almost a fifth): the share of wind energy was 14%, and the share of solar - 5% [6-9].

The leaders in the production of wind and solar energy in the EU are shown in Figure 3.

As is obvious from the figure, in 2020 the largest share of solar and wind energy in electric power was obtained in Germany (50%), Denmark (48%), Ireland (38%) and Spain (37%).

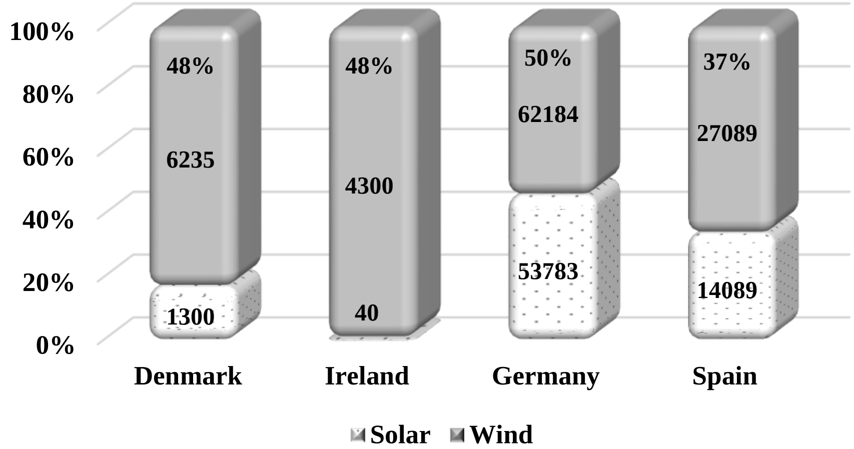

Figure 3. Leaders in the production of wind and solar energy in the EU

CURRENT STATE AND FORECASTS OF RES IN AZERBAIJAN

The total capacity of electric power produced in Azerbaijan is 7516 MW, of which 1278 MW is the capacity of power plants using renewable energy sources, including large hydroelectric power plants, which is 17% of the total capacity. At that, the hydropower plant capacity is 1135 MW (22 plants, 12 small HPPs), wind energy is 66 MW (5 plants, 1 hybrid), bioenergy capacity is 38 MW (2 plants, 1 hybrid), solar energy capacity is 40 MW (9 plants, 1 hybrid).

In 2020 the electricity generation in the country amounted to 25.8 billion kWh, of which 24.3 billion kWh fall on thermal power plants and 1,069.5 million kWh fall on hydropower plants. The electric power generation at wind and solar power plants and at solid waste incineration plant amounted to 343.55 million. During the year, 96.1 mln. kWh of electric power was produced at wind farms, 46.9 mln. kWh at solar power plants and 200.6 mln. kWh at solid waste incineration plant. Thus, the electric power produced from renewable energy sources accounted for about 6% of the total production.

Azerbaijan is one of the world's oldest oil and gas producing countries (with proven oil reserves of more than 1 billion tons by 2019, as well as about 2.1 trillion cubic meters of natural gas reserves, as well as great potential for renewable energy development [10-12].

The country has high wind and solar resources and significant prospects in terms of biomass, geothermal and hydropower plants -> 500 MW for hydropower, solar FV> 23000 MW, wind (on-shor)> 3000 MW, waste / bioenergy is 380 MW, with a total of> 27,000 MW. In addition, the potential for additional renewable heat (biomass, solar thermal, geothermal) for independent systems in remote rural areas is estimated at approximately 0.6 MNET / year. In order to realize this potential, the Government adopted a Strategic Roadmap in 2016. It had planned to increase its renewable energy source by 420 MW by 2020. Guided by this goal, several contracts have been signed for the construction of BEM (Khizi and Pirakushkul WPP, with an installed capacity of 240 MW, Alat PVPP, 230 MW) and in the Karabakh region with a capacity of more than 300 MW. and preliminary feasibility studies for the construction of the PVPP are being implemented. At the same time, the introduction of the "net metering" rule in the calculation of electricity will lead to the emergence of small strong VRES-based active consumers in individual homes over the next 5 years. It is estimated that the total capacity of such sources may exceed 1,000 MW. In other words, the total volume of VRES in the next five years can be projected at more than 2,000 MW, which allows us to predict that the share of EES in installed capacity will be more than 25%.

Renewable energy sources also offer a sufficiently low-carbon solution to achieve Azerbaijan's goals under the United Nations Framework Convention on Climate Change. The country has committed to a 35% reduction in green hose emissions by 2030 compared to the base year, adopted in its National Contributed Document (NDC) under the Paris Agreement, and the use of RES is particularly important to achieve this goal.

"Green growth" occupies one of the central places in the National Priorities of Azerbaijan 2030: socio-economic development of the Republic of Azerbaijan. At the same time, green development is of particular importance in the implementation of the commitments of the United Nations, of which Azerbaijan is a partner, "Transformation of our world: Agenda for Sustainable Development until 2030."

Variable renewable energy sources (VRES) have significantly increased the importance of flexibility and energy security in power systems (PS) against the backdrop of the widespread use of renewable energy sources. At the same time, new threats, from cybersecurity to rapidly changing weather conditions, require steady attention from governments. According to estimates, almost 1/5 of the increase in global energy consumption in 2018 was due to changes in weather conditions, i.e.

cooling on hot summer days, and additional heating needs in cold weather. On July 21, 2021, due to the high temperature in the Azerbaijan territory, the demand for maximum power and the production of daily electricity increased by an average of 12% [13-16].

At present, the share of energy sources in the capacity of Azerbaijan's thermal power plants is about 84% of conventional sources and BEM of 16% (Figure 1). 14%). SES has a major share (90%) in the structure of BEM. On average, 90% of renewable energy generation capacity is regulated BEM-class hydropower plants (Figure 4, 5).

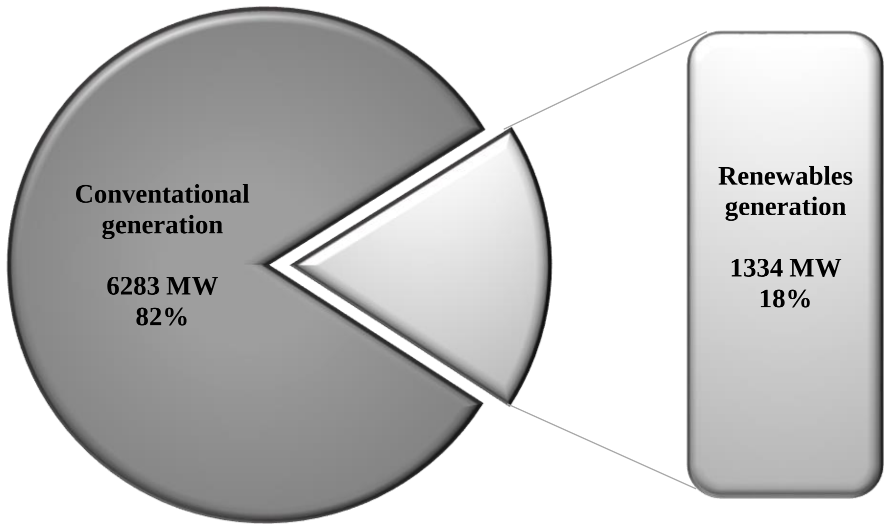

Figure 4. Structure of generation source, MW, %

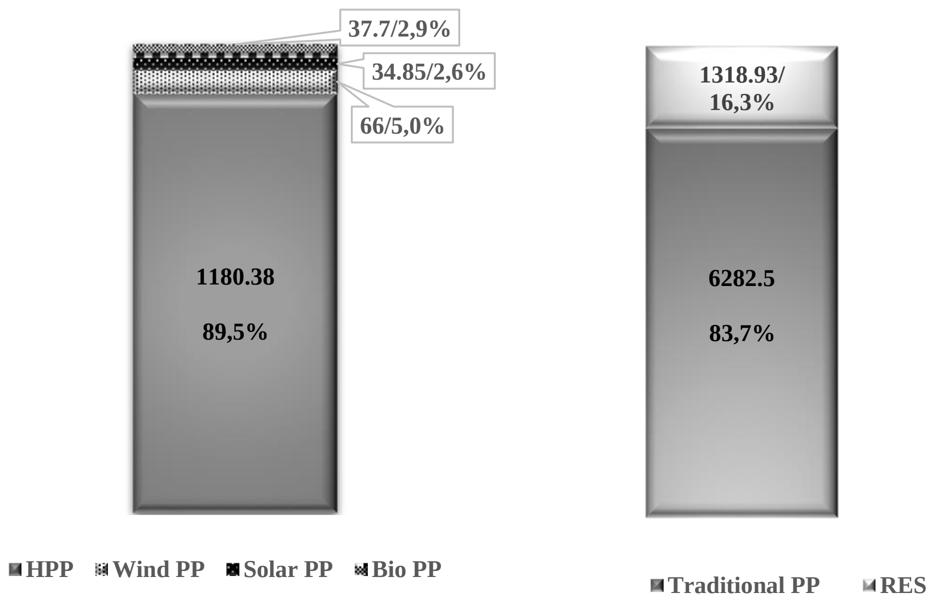

Figure 5. Structure of energy sources, MW, %

Azerbaijan is one of the countries rich in renewable energy sources. Our goal is to increase the share of renewable energy sources in electricity generation to 30% by 2030, in order to ensure the efficient use of the potential of solar and wind energy. In this regard, by 2030 it is planned to commission about 1500 MW of new capacity. It is planned to do this through private investment (Table 1).

Table 1

2020-2022	2023-2025	2026-2030
470 MW	460 MW	570 MW

PROBLEMS OF INTEGRATION OF RES IN POWER SYSTEM

The increase in the share of generation based on wind and solar in the structure of the electric power industry in many countries and regions poses certain challenges for energy managers. How can an increasing proportion of unstable energy flows be safely integrated into the grid with the least energy loss and without compromising system reliability?

To date, a large amount of empirical data has been accumulated regarding the management of the network economy in the context of a high share and even dominance of renewable energy sources. Moreover, there is no shortage of theoretical studies and models of systems based on renewable energy sources.

The integration of small volumes of changeable RES into the grid is not a problem. Small volumes here mean a share of 5-10%.

In this case, you still need to follow some rules:

• Avoid uncontrolled local concentrations of RES (“hot spots”);

• Ensure that RES power plants can “help” stabilize the grid when needed;

• Forecast electricity production from renewable energy sources and use these forecasts to plan the operation of other power plants and electricity flows in the grid.

Research in the regions of the project showed that the current level of flexibility of power systems technically allows "work" with an annual share of variable generation of 25-40%. According to the same analysis, "in very flexible systems" the share of RES can exceed 50% levels if the possibility of forced shutdowns of "small volumes" of generation based on renewable sources is allowed.

The integration of large volumes of renewable energy sources requires the transformation of the energy system as a whole. In other words, we are not talking about a simple addition of new generation objects to the "old" system that works as usual, but about a complete reformatting of the system.

The costs associated with this transformation depend on different circumstances. Obviously, if a high share of renewable energy sources is added at a time (which, in general, does not happen), then system costs increase significantly. On the other hand, with a gradual development (taking into account a decrease in the cost of renewable energy technologies and, on the contrary, an increase in environmental charges in the future), zero or even negative growth of system costs is possible.

Increase in volumes of energy use from renewable sources not only reduces the volume of emission of carbon dioxide and other gases into the atmosphere, but also has a number of other advantages:

- RES are practically inexhaustible sources of energy, which helps in reducing dependence on depletable traditional energy sources such as oil, natural gas, coal, etc.

- They are domestic sources of energy and contribute to strengthening energy independence and security of energy supply at the national level.
- They are geographically dispersed, which leads to decentralization of power system, which lowers the load on infrastructure systems and reduces losses from energy transmission.
- They usually have low running costs, which are not affected by fluctuations in international markets and especially the prices of conventional fuels (crude oil, natural gas, coal).
- Relatively shorter commissioning time for RES plants.

RES installations are usually designed to the satisfaction of specific energy users / consumers, in both large and small scale, and have a relatively short start-up (mobilization) time, which allows a quick response to energy supply in accordance with energy needs.

- Investments in RES create a significant number of new jobs, especially at the local level.

Along with the advantages, RES also have a number of disadvantages:

- Fossil fuel still generate large amount of electric power. Actually, this means that one cannot rely exclusively on RES.
- Renewable energy source technologies are completely dependent on the weather. In case atmospheric conditions are not good enough, renewable energy source technologies will not be able to produce electricity.
- The creation of renewable energy production capacities requires huge financial costs. For the construction of plants, the preliminary investment, high maintenance costs and careful planning and implementation are required. In addition, the generated electric power must be delivered to the cities, which means additional costs for the installation of power lines.
- A lot of space is required for RES plants.
- High storage costs [13-15].

1. The technical impact of the use of RES on the power generation system

The technical impact of RES on the generation system is inevitable.

One of the important features of RES (especially solar and wind) is that they have daily and seasonal fluctuations. This variable form of energy partially allows for performing a dispatching control.

Another impact of the widespread use of RES on the generation system is its (RES) excess production at minimum electric power demand. In this case, it becomes necessary to reduce the capacity of the base power plants to a minimum (in the power system of Azerbaijan, this is mainly the Azerbaijan TPP). The dispatcher must be able to control the variable nature of generation to ensure the stability of the power system operation mode.

When there is a lot of RES energy and there is no need for it, the energy storage mode (for example, through a pumped storage power plant, battery, etc.) increases the efficiency of RES energy use, but in this case, the energy storage requires large investments [16-18].

2. The technical impact of the use of RES on the electricity transmission and distribution system

The widespread use of distributed generation (including RES) during operation leads to an increase in uncertainty, which must be taken into account by the dispatcher (system operator) when making operational decisions. The power system must be able to quickly (efficiently) reduce generation at decrease in demand and have an operational power reserve.

The dispatcher must respond to sudden changes in power flows, changes in flows may limit the transmission of electricity, and in some cases may cause a failure (emergency). Sharply variable generation powers can also adversely affect electric power quality, which can manifest as harmonics and twinkling.

The negative impact of RES is observed in these issues, including the sustainability of power system, the maintenance of reactive power and the provision of inertia, as well as the safety of power system.

According to the generally accepted rule, the reserve power in the power system is accepted equal to the power of the largest generation unit or the power lost due to the opening of line transmitting the electric power. Significant changes in RES-based generation can tighten requirements for both reserve power volume and power start-uprate. There may be a need to create new types of reserve power types and itsactivation system.

In addition, for example, the operation of wind farm can affect the quality of electric power and cause the formation of harmonics at the junction and overvoltage due to the electromagnetic transition process. A sharp loss of RES-based generation can lead to the following for the power system: exceeding the operating limits for power lines and equipment, as well as exceeding the stability limits of the power system; decrease of voltage resistance and control characteristics, reduction of dynamic stability and frequency adjustment characteristics of EES [13].

3. Possible problems during the operation of RES

Replacement of traditional generation with increasing RES leads to thedecrease in possible operational options during operation and new problems:

- the problem of maintaining the required level of voltage, RES usually do not participate in the dynamic regulation of reactive power / voltage;
- the problem of keeping the short-circuit current at the required level to ensure the selective operation of the relay protection, rectifiers that connect the RES to the network usually do not perform this function;
- the problem of overload prevention, small energy facilities usually are not controled (for example, solar plants in low-voltage systems);
- the problemof overloadingcontrol of networks due to the priority of transmission of electric power generated by RES.

CONCLUSIONS

1. The growing development of RES in the world is an effective tool for preventing climate change.
2. Azerbaijan has extensive opportunities to use solar and wind energy.
3. Extensive use of RES in Azerbaijan will have positive effects such as reduced CO_2 emissions and gas fuel savings.
4. The widespread use of RES has the potential to have a significant impact on the generation system, transmission and distribution system. Replacement of traditional generation with increasing RES leads to new problems such as reduction of possible operational options during operation and violation of the selective operation of relay protection of short-circuit current, failure to ensure the required level of equivalent inertia constant.

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THE PROBLEM OF RATIONAL FLOW DISTRIBUTION IN ELECTRIC NETWORKS OF POWER SYSTEMS AND WAYS ITS SOLUTION

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Abstract. In a real power system, there are often situations of uneven loading of the supply lines included in the section, forming a connection between the source and the power system or a separate dedicated load node. In such situations, one of the transmission lines will be loaded below the rated capacity, while the other parallel transmission line will be overloaded. The emergence of irrational active flow distribution in the adjacent non-uniform electrical networks of the 220/110 kV Azerenerji power district makes it necessary to use an unreasonable limitation of the generation power or consumption.

On the example of modeling and computational experiments carried out in the energy system of Azerbaijan, the effectiveness of applying voltage phase angle control in the power system with significant uneven load in controlled sections of the system's supply network is shown. An analysis is given of the effect of eliminating unevenness on reducing losses in the network and increasing the efficiency of using power generation at stations. The results of computational experiments are presented, confirming the efficiency of the phase-shifting transformer in the considered Azerenerji power region in normal, post-emergency and repair modes.

Key words: power system, heterogeneous electrical network, redistribution of power flows, voltage phase angle control, phase-shifting transformer, power losses, voltage, repair mode.

ENERJİSİSTEMİN ELEKTRİK ŞƏBƏKƏLƏRİNDƏ GÜC AXINLARININ RASİONAL PAYLANMASI PROBLEMİ VƏ ONUN HƏLL ÜSULLARI

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Xülasə. Real enerjisistemdə mənbə və enerjisistem və ya ayrı-ayrı ayrılmış düyün yükləri arasında əlaqəni formalaşdıran şəbəkələrə daxil olan qidalandırıcı xətlərin qeyri-bərabər yüklənmə problemləri yaranır. Belə şəraitlərdə elektrik veriliş xətlərindən bir qismi nominaldan aşağı, digər paralel işləyən qismi isə artıq yüklənir. Azərenerji sisteminin 220/110 kV gərginlikli qeyri-bircins elektrik şəbəkələrində qeyri-bərabər aktiv güc axınlarının yaranması tələbat və ya generasiya güclərinin əsaslandırılmayan məcburi məhdudiyyətlərinin tətbiqini şərtləndirir.

Azərbaycan enerjisisteminin real sxemi üzrə aparılmış modelləşdirmə və hesabi təcrübələr əsasında sistemin qidalandırıcı şəbəkələrinin nəzarət olunan kifayət dərəcədə qeyri-bərabər yüklü sahələrində gərginliyin faza bucağının idarəolunmasının effektivliyi göstərilmişdir. Qeyri-bərabərliyin aradan qaldırılmasının şəbəkədə itkilərin azaldılmasına və stansiyalarda istehsal olunan elektrik enerjisindən istifadə səmərəliliyinin artırılmasına təsirinin analizi verilmişdir. Azərenerjinin baxılan enerji rayonunda normal, qəzadan sonrakı və təmir rejimlərində fazadəyişdirici transformatorun tətbiqinin effektivliyi hesabi təcrübə nəticələri əsasında təsdiq edilir.

Açar sözlər: enerjisistem, elektrik şəbəkəsi, güc axınlarının yenidən paylanması, gərginliyin faza bucağının tənzimlənməsi, fazadəyişdirici transformator, gücv itkisi, gərginlik, təmir rejimi.

ПРОБЛЕМА РАЦИОНАЛЬНОГО РАСПРЕДЕЛЕНИЯ ПОТОКА В ЭЛЕКТРИЧЕСКИХ СЕТЯХ ЭНЕРГЕТИЧЕСКИХ СИСТЕМ И СПОСОБЫ ЕЕ РЕШЕНИЯ

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Аннотация. В реальной энергосистеме часто возникают ситуации неравномерной загрузки питающих линий, входящих в сети, образующих соединение между источником и энергосистемой или отдельным выделенным узлом нагрузки. В таких ситуациях одна из линий электропередачи будет загружена ниже номинальной мощности, а другая параллельная линия будет перегружена. Возникновение нерационального активного потокораспределения в прилегающих неоднородных электрических сетях 220/110 кВ энергорайона системы Азерэнержи заставляет использовать необоснованное ограничение мощности или потребления генерации.

На примере моделирования и вычислительных экспериментов, проведенных по реальной схеме энергосистема Азербайджана, показана эффективность применения управления фазового угла напряжения в энергосистеме со значительной неравномерной нагрузкой на контролируемых участках питающей сети системы. Дан анализ влияния устранения неравномерности на снижение потерь в сети и повышение эффективности использования выработки электроэнергии на станциях. Приведены результаты вычислительных экспериментов, подтверждающие эффективность работы фазоповоротного трансформатора в рассматриваемой энергорайона Азерэнержи в нормалных, послеаварийных и ремонтных режимах.

Ключевые слова: энергосистема, гетерогенная электрическая сеть, перераспределение потоков мощности, регулировка фазового угла напряжения, фазосдвигающий трансформатор, потери мощности, напряжение, ремонтный режим.

INTRODUCTION

The control of power flows in the electrical networks of the power system is the main means of maintaining the reliability and efficiency of its operation. In high voltage supply and distribution networks, flow control is carried out by regulating the voltage and reactive power in the controlled nodes of these networks. One of the properties of the power grids of the power system that determine the need for the prompt redistribution of power flows is the heterogeneity, uneven congestion of high-voltage power transmission lines (TL) in the supply and distribution networks, as well as the periodic need to correct the mode to meet the conditions for minimum losses in these networks.

To solve the problems of controlling the power system mode, taking into account the indicated properties, various methods and software and hardware have been developed. For example, to eliminate inhomogeneity, various approaches are proposed based on opening the circuit of closed networks [1]. Disconnection methods do not always justify themselves due to the high cost of practical implementation and a significant weakening of the reliability of power supply.

Another group of approaches to eliminate the inhomogeneity of closed electrical networks is based on the forced change of the parameters of the network diagram by connecting FACTS (Flexible Alternative Current Transmission Systems) [2]. One of the options for this approach is the longitudinal compensation of the parameters of the transmission line in the supply network [3-5].
In this work, studies have been carried out on the application of voltage phase control on lines that form a parallel connection between the source and the power system and have varying degrees of

uneven load on these power lines. One of the means of voltage regulation in order to redistribute the flows of active and reactive power in the network, eliminate the unevenness of the load of lines in the sections that provide the transfer of power from power plants to the power system, are phase-shifting transformers (PST) [6].

PST have been used in world practice since 1969. In 2009, for the first time in the history of the CIS, a 500/220 kV PST with a capacity of 400 MVA was installed at 500 kV Ulka SS in Kazakhstan. PST made it possible to regulate the phase shift in the range of 0-700 and the unit was designed and manufactured by the company “Zaparozhtransformator” [7].

In 2019, on April 18, the Volzhsky HPP of Russia put into operation PST with a voltage of 500/220 kV with a capacity of 195.26 MVA with the participation of JSC STC UES and JSC Institute Hydroproject. Evaluations of the financial indicators of the options excluding the generation limitations of the Volzhkaya HPP indicated that the use of PST in comparison with the installation of an additional 220 kV transmission line requires 2.5 times lower capital costs [8].

Taking into account the above, to eliminate the natural irrational flow distribution of active power in the Absheron 220/110 kV power region in the Azerenerji system, the question of installing a PST was raised, which should ensure the economic flow distribution of active power through the adjacent networks of the Shimal-1 and Shimal-2 power plants. It was justified to install the PST complex in normal, repair and post-emergency circuit-regime situations of this power district.

1. MODEL AND CIRCUIT FOR REGULATING THE PHASE ANGLE OF THE VOLTAGE IN THE POWER SYSTEM BASED ON THE PST

The control of the active power flow of the line can be carried out by changing the phase angle or by changing the reactance of the given line. The change in reactance can be accomplished by placing capacitive elements along the line to compensate for the line inductance.

Basically, to redistribute the flow in the transmission network and reduce the load on one of the lines outgoing from the source, the phase of the angle between the voltage vectors at the beginning and end of the line is regulated. The power flow in the transmission line can be increased by increasing the phase angle. The amount of additional increment of the angle is controlled in a certain specified interval. In accordance with the relationship between the phase angle and the additional shift of the voltage phase angle upward, two types of regulation are proposed [7,8]:

- regulation of the phase and voltage value (the angle between the voltage phase and the additional increment of the phase angle, varies between 0 ° and 90 °);

- regulation of the phase angle (angle between voltages).

Figure 1 shows a diagram of a supply network consisting of parallel transmission lines, in one of which the connection between the source and the consumption node is carried out on a different voltage class with the connection of the PST.

In the absence of a switched-on PST, the currents in the lines I_1 and I_2 will be distributed in proportion to the values of their impedance, respectively:

$$I_1 = \frac{X_2}{X_1 + X_2} \cdot I \tag{1}$$

$$I_2 = \frac{X_1}{X_1 + X_2} \cdot I \tag{2}$$

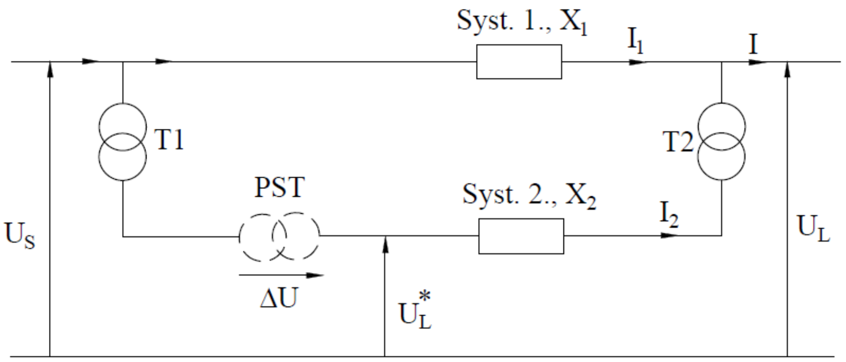

Fig. 1. Typical diagram of two parallel power transmission systems

With an increase in power in power transmission line-2, additional voltage must be applied to compensate for the voltage drop in this power transmission line.

In principle, the source can be connected to either of the two parallel systems. In fig. 2 shows vector diagrams of voltages for two cases of PST connection.

Fig. 2 corresponds to the case of connection to power transmission line-2 (Fig. 1), which has a high impedance. The additional voltage reduces the voltage drop in the power transmission line-2.

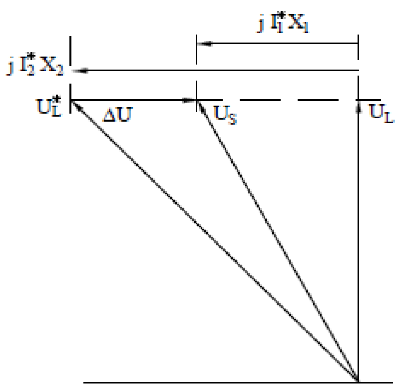

Fig.2. Vector voltage diagram when using PST (PTL 2 phase lead - U^*_L advances U_S

Another very important application of PST is to control the flow of active power between two large independent power interconnections (EU) (Fig. 3). The leading phase angle is necessary in order to maintain the power flow from EO-1 to EO-2.

$$U_S + \Delta U - I^* jX - U_L = 0 \tag{3}$$

at $U_S = U_L = U$

$$\Delta U - I^* jX = 0 \tag{4}$$

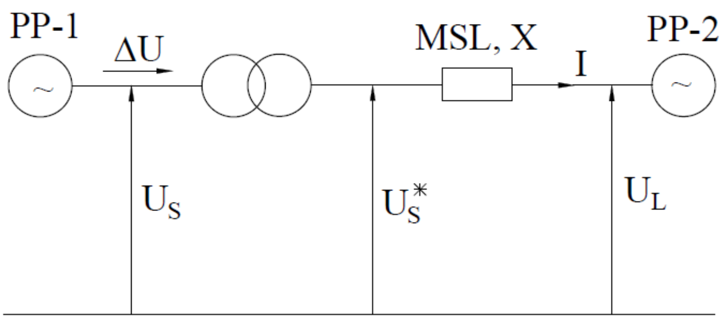

Fig. 3. Intersystem communication

We consider aspects of the PST application as an innovative solution to the problem, which allows to exclude the forced restriction of the transmission load in the adjacent 220/110 kV electrical networks in repair and post-emergency circuit-regime situations of the Azerbaijani power system. Such a solution, due to the economical distribution of active power (and / or reactive

power) between switchgears 220 and 110 kV, makes it possible to increase the throughput of electrical networks, transmission by all the power plants located at Shimal-1 and Shimal-2, of this power district, as well as the flexibility of managing the loading of 220-110 kV transmission lines.

2. THE USE OF VOLTAGE PHASE ANGLE CONTROL TO REDISTRIBUTE THE ACTIVE POWER FLOW INTO THE SUPPLY NETWORK OF THE AZERENERJI SYSTEM.

The studies were carried out for a section of a system-forming 220/110 kV network connecting the Shimal steam-gas power plant (Shimal-1 and Shimal-2) with the power system through parallel operating 110 kV and 220 kV transmission lines.

Due to the limitation of the transmission capacity of 110 kV electrical networks in the area of the Shimal-1 and Shimal-2 power plants, there is a threat of exceeding the permissible values of operating parameters in repair and post-emergency modes and, accordingly, it becomes necessary to limit the power output of the power plant or the load of consumers. For example, during an emergency shutdown of transmission line 4 Shimal 110 kV, transmission line 5 Shimal 110 kV, up to 99.3 MW (545 A) are loaded, and at the same time, the load of power lines 3 and 4 of Hovsan 220 kV is 112.6 MW (340 A). At this time, when one of the transmission lines 4 and 5 Shimal 110 kV is taken out for repair or emergency shutdown, depending on the air temperature, the load of the transmission line remaining in operation goes beyond the permissible limit. Therefore, in such cases, the application of restrictions is inevitable.

3. ANALYSIS OF THE RESULTS OF THE USE OF PST IN AZERENERJI.

As indicated above, in a normal scheme in various circuit-mode situations (disconnection of transmission lines 4 Shimal 110 kV, simultaneous disconnection of transmission lines 1 and 4 Shimal 110 kV, disconnection of transmission lines 1.4 Shimal 110 kV and transmission line 3 Hovsan 220 kV, etc.) the load of the 5 Shimal 110 kV transmission line, depending on the air temperature, may go beyond the permissible limit and, as a result, the power output of the station in full will become impossible. At the same time, the volume of restrictions, depending on the season and the load regime, is approximately 60 MW (6.25% of the installed capacity of power plants).

In fig. 4 shows the profiles of the current loads of the branches according to the normal scheme with and without PST. As can be seen from the figure, when the PST is installed on the Shimal ES, the current loads of the 4.5 Shimal 110 kV transmission line are reduced from 390 A to 260 A, while the degree of power loss reduction is 1.7%. The current loads of other 110 kV transmission lines also decrease and the load of the adjacent networks is relatively equalized. The current load of transmission lines 3.4 Hovsan 220 kV rises from 320 A to 370 A, and transmission lines 3, 4 Zabrat 220 kV to 280 A.

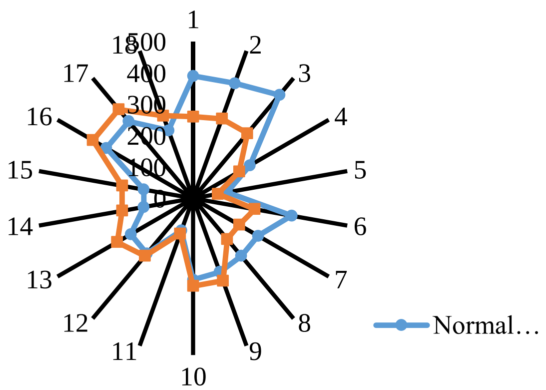

Fig. 4. Profiles of currents for the branches of the energy region along the normal scheme in the presence and absence of PST

4. RATIONALE FOR THE USE OF PST IN VARIOUS CIRCUIT-MODE SITUATIONS

Studies on the effectiveness of PST in repair and post-emergency modes, numerous operating calculations were carried out according to the criteria N-1 and N-2. In order to substantiate the use of PST, studies were carried out in the absence and presence of PST for a comparative assessment of the results of computational experiments.

First, according to criterion N-1, the cases of shutdown of the Shimal-1 and Shimal-4 power lines were considered and the load of 110 and 220 kV power lines in the absence and presence of PST was investigated and the results of calculations in the form of current profiles along the branches of the electric networks of the power region are illustrated in Fig. 5.

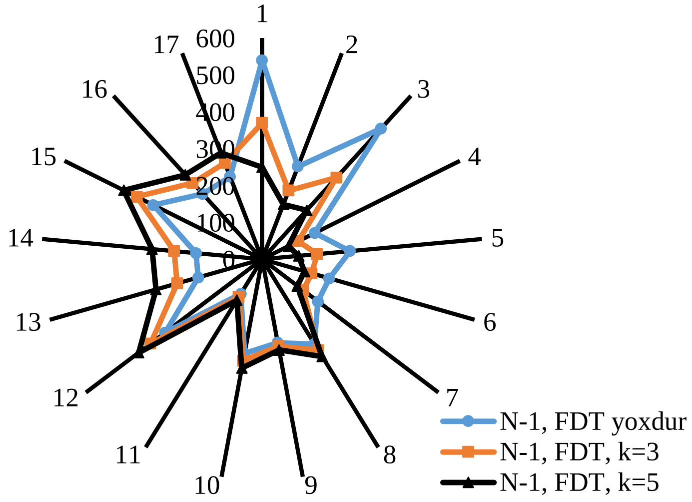

Fig. 5. Profiles of currents along the branches of the circuit according to N-1 (disconnections TL Shimal-4) in the absence and presence of PST

As can be seen from both figures, in the cases considered, with the action of the PST, the unloading of 110 kV transmission lines and the loading of 220 kV transmission lines occur, and thus, an economical distribution of power arises over the adjacent electrical networks.

Cases of simultaneous shutdown of transmission lines Shimal-1 and Shimal-2 110 kV on N-2 are considered (i.e. the state of being in repair of one of the lines and emergency shutdown of the other line from protection). Figure 6 shows for the considered case of current loads of network elements. As you can see, there is an effective distribution of the loads of 110 and 220 kV transmission lines under the action of PST.

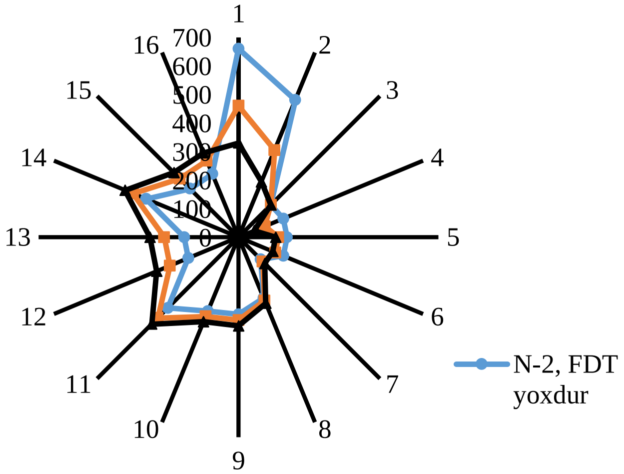

Fig. 6. Profiles of currents flowing along lines with no and presence of

PST on N-2 (disconnection of power lines Shimal-1 and Shimal-2)

Summing up, it can be confirmed that in order to ensure effective flow distribution in the adjacent electrical networks of the 220/110 kV power district of the Azerenerji system, it is more preferable to install PST in the circuit of autotransformers for communication between the buses 220 and 110 kV of the Shimal ES.

CONCLUSIONS

2. It has been determined that the transition to forced power distribution can provide an economical flow distribution for the considered power region. For this purpose, a variant of the use of PST in the circuit of autotransformers of communication, installed between the buses of 220 kV and 110 kV of ES Shimal, is considered.

3. To determine the efficiency of PST, studies of flow distribution in repair and post-emergency modes were carried out. The results obtained on the profiles of the power transmission line currents and the value of the power loss confirm the need to install PST in the 220/110 kV communication autotransformers circuit of the Shimal ES of the Azerenerji system.

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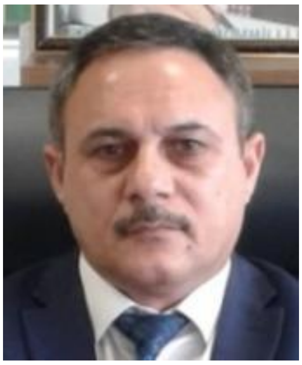

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MODERN DIAGNOSTIC CONTROL SYSTEM OF TRACTION MOTORS

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Abstract: The article is devoted to the control of the main operating parameters of the traction electric motor in the operation process by modern methods and tools. In order to simulate the control of possible failures in the motor, magnetic field, vibration, sound, temperature sensors were installed on a small powerful asynchronous motor in the laboratory, and the data received from sensors in normal and overload modes of the motor were studied. As a result of experimental studies, the application of the selected methods and tools in the early assessment of the technical condition of high-power electric motors, especially traction motors, will increase the effectiveness of diagnostic control, thus ensuring more reliable operating conditions of motors.

Keywords: traction motor, diagnostics, magnetic field control, sound level control, vibration control, temperature control

DARTI MÜHƏRRİKLƏRİNİN MÜASİR DİAQNOSTİK NƏZARƏT SİSTEMİ

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Xülasə: Məqalə istismar prosesində dartı elektrik mühərrikinin əsas işçi parametrlərinə müasir üsul və vasitələrlə nəzarət olunmasına həsr olunmuşdur. Mühərrikdə yarana biləcək nasazlıqlara nəzarəti imitasiya etmək üçün laboratoriya şəraitində kiçik güclü asinxron mühərrikin üzərində maqnit sahəsi, vibrasiya, səs, temperatur vericiləri quraşdırılmış, mühərrikin normal və artıq yüklənmə rejimlərində vericilərdən alınan məlumatlar tədqiq edilmişdir. Aparılan eksperimental tədqiqatların nəticəsi olaraq seçilmiş üsul və vasitələrin böyük güclü elektrik mühərriklərin, xüsusilə dartı mühərriklərin, texniki vəziyyətinin erkən qiymətləndirilməsində tətbiqi diaqnostik nəzarətin effektivliyini artırmış olacaq beləliklə mühərriklərin daha etibarlı iş şəraiti təmin olunacaqdır.

Açar sözlər: dartı elektrik mühərriki, diaqnostika, maqnit sahəsinə nəzarət, səs səviyyəsinə nəzarət, vibrasiya nəzarəti, temperatura nəzarət

СОВРЕМЕННАЯ СИСТЕМА ДИАГНОСТИКИ КОНТРОЛЯ ТЯГОВЫХ ДВИГАТЕЛЕЙ

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Аннотация: Статья посвящена вопросам контроля основных рабочих параметров тягового электродвигателя в процессе эксплуатации современными методами и средствами. С целью имитации контроля возможных неисправностей в двигателе, в лабораторных условиях на небольшой мощный асинхронный двигатель были установлены датчики магнитного поля, вибрации, звука, температуры и исследованы данные, полученные от датчиков в нормальном и перегрузочном режимах двигателя. В результате экспериментальных исследований применение выбранных методов и средств при ранней оценке технического состояния мощных электродвигателей, особенно тяговых, позволит повысить эффективность

диагностического контроля, тем самым обеспечить более надежные условия эксплуатации двигателей.

Ключевые слова: тяговый двигатель, диагностика, контроль магнитного поля, контроль уровня звука, контроль вибрации, контроль температуры.

INTRODUCTION

Stopping the traction electric motor (TEM) due to any failures during operation creates great difficulties in traction. To avoid such problems, it is possible to predict faults in TEM. To do this, a list of faults must be compiled and the normal and threshold values of the main informational parameters involved in the occurrence of these faults must be determined. By constantly monitoring the parameters, it is possible to monitor changes in the motors and draw conclusions about these changes. By diagnosing the mechanical and electrical parts of a TEM, its technical condition is assessed and the part or junction that may cause the fault is precisely identified.

STATEMENT OF THE PROBLEM. In recent years, a lot of research has been conducted to create new methods to monitor the technical condition of electric motors, to overcome the shortcomings of traditional methods. Only the temperature parameter is used to perform diagnostic monitoring of the current operating condition of TEM manufactured by a number of leading companies in the world. The results of the research show that a single temperature parameter does not provide complete and complete information about the technical condition of the motor, and a number of faults need to be added to these parameters to obtain more accurate results, as the initial temperature control can not be determined. For this reason, the creation of a comprehensive diagnostic control system for TEM is urgent [1-3].

The main purpose of the study is to carry out direct diagnostic monitoring of TEM in working condition.

SOLUTION OF PROBLEM. In the research, a complex diagnostic control system of electric parts of TEM was developed and the model of the system in the laboratory was based on a small powerful motor. The main informative parameters of the complex diagnostic control system are temperature, magnetic field control, acoustic control, vibration control. Operational and technical characteristics and functional capabilities of different types of sensors were studied to monitor the main parameters mentioned above.

Magnetic field control. One of the most modern and promising methods selected for diagnostics of the TEM during operation is the measurement of the magnetic field and spectral analysis. An experimental stand based on a small powerful asynchronous motor type GD190 / 4HD has been developed to simulate the possible failures of the TEM in the laboratory and to control changes in the basic parameters. Operational and technical characteristics and functional capabilities of different types of sensors have been studied to monitor the main parameters listed above [4-7].

The results of the analysis show that the defects and faults in the electric motor have a significant effect on the spectrum of the electromagnetic field generated outside it. By analyzing the spectrum of the external magnetic field, it is possible to speculate about the failure of TEM. In studies, the use of a Hall sensor as a sensor that allows non-contact diagnostics without interfering with motor design has been preferred. Thus, this sensor can be considered one of the most informative sensors that allows you to assess the condition of the motor by monitoring the electromagnetic spectrum. The traditional connection scheme for this type of sensor is shown in Figure 1.

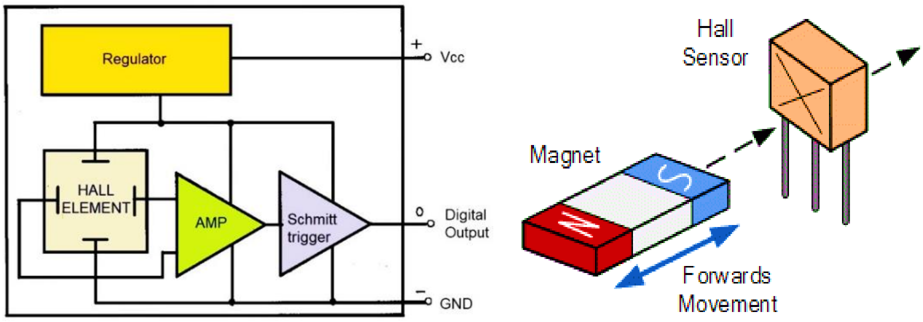
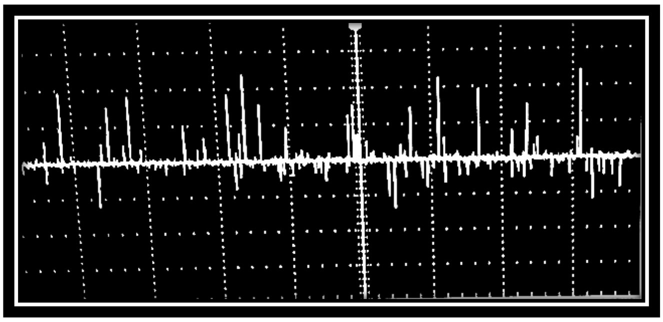


Figure 1. Traditional connection scheme of modern Hall sensors

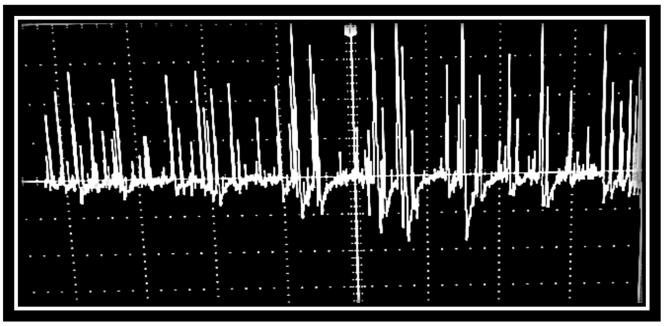
Various examples of mass-produced Hall sensors are shown in Figure 2. During the experimental studies, the use of KY-024 Hall sensor, distinguished by its performance, was preferred.

Figure 2. Constructive descriptions of Hall magnetic sensors

The oscillograms of the magnetic field change in different modes of the motor studied using the KY-024 Hall sensor is shown in Figure 3. The oscillograms were recorded and analyzed using a **Tektronics TSB**-type oscilloscope.



a)



b)

Figure 3. Recorded oscillograms of magnetic field changes: a) during normal operation; b) in case of overload

As can be seen from the analysis of oscillograms, magnetic field control can be selected as one of the most important parameters for complex diagnostic monitoring of the motor.

Vibration control. Another important informative parameter for diagnostic monitoring of TEM failures is the importance of vibration control. All electric motors have normal vibrations, but abnormal vibrations do occur. Increased current frequency, collapse of pads, change of air pore between rotor and stator, weak connections, etc. problems are the causes of vibration.

Vibration sensors are divided into two groups according to their design and application characteristics: vibration speed and vibration sensors. Due to the large number of disadvantages, vibratory sensors are not used in practice. The latter are divided into piezoelectric accelerometers and vibration capacitors according to the principle of operation and construction. The advantages of piezoaccelerometers are the availability of a wide frequency range, low weight and high sensitivity. The disadvantages are the impossibility of application without checking the resonance properties and the relatively high cost. At present, three-coordinate sensors are also widely used [8].

The advantages of vibration capacitors are the ability to record extremely low frequency vibrations, high sensitivity, and the fact that the voltage at the output of the sensor does not change significantly during rotation. The main disadvantages of capacitive vibration sensors are the low operating frequency upper limit (200..1000 Hz) and the difficulty of determining inertia.
A constructive view of the vibration sensors used in the experimental studies is given in Figure 4.

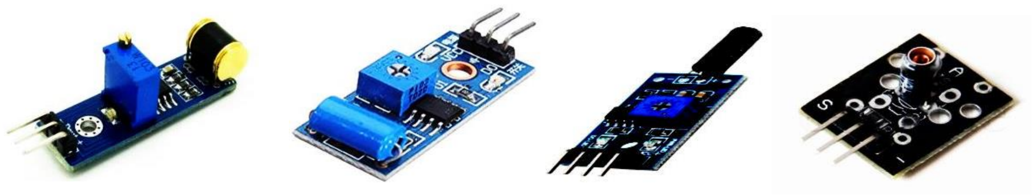
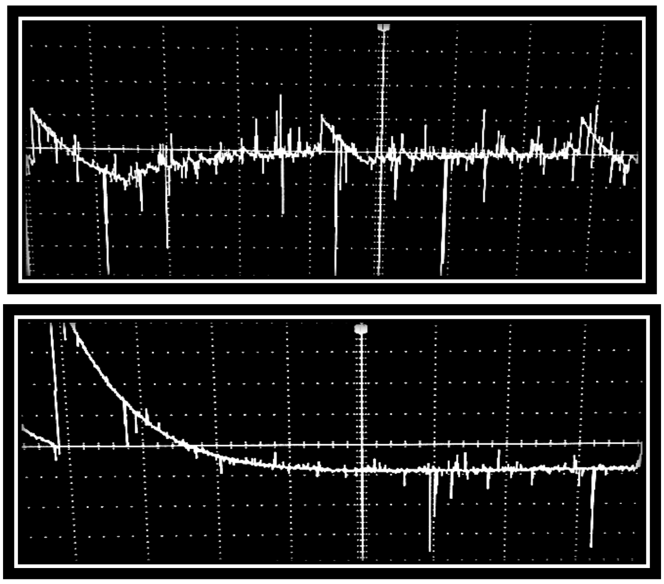


Figure 4. Constructive descriptions of vibration sensors

The oscillograms of the vibration spectra recorded in the experiments using the SW-18015P capacity vibration sensors are shown in Figure 5.



a)

b)

Figure 5. Oscillograms of vibration spectra: a) during normal operation; b) in case of overload

As can be seen from the analysis of oscillograms, we observe an increase in the vibration of the motor when comparing it with the normal operating mode. This makes it possible to include the vibration parameter in the proposed complex diagnostic monitoring system.

Acoustic control. Acoustic diagnostics is now widely used in many fields. Acoustic diagnostics is mainly based on comparing the noise level of the machine with the noise of the machine in normal working condition.

Noise level changes are mainly used to detect mechanical faults. However, a decrease in the electrical strength of the insulation in the stator and rotor windings is also among these faults. Vibration failures also affect the sound level. Therefore, acoustic diagnostics is carried out in parallel with vibration diagnostics [9-11].

A piezoelectric converter was considered more appropriate to determine the noise level caused by a failure in the motor. The main elements of the piezoelectric converter are a membrane elastic element, a crystal, a connecting link mechanism, a voltage amplifier. When the membrane is exposed to any pressure, this effect is transmitted to the crystal through a lingel mechanism, and a very small voltage is created in the crystal. The stress in the crystal is directly proportional to the pressure applied to the membrane. Since the voltage across the crystal is very small, its value must be increased.

In the laboratory, oscillograms were recorded using a 7BB-27-4L0 piezoelectric monitor (Figure 6) to control the sound level, taking into account the characteristics of the electric motor (Figure 7).

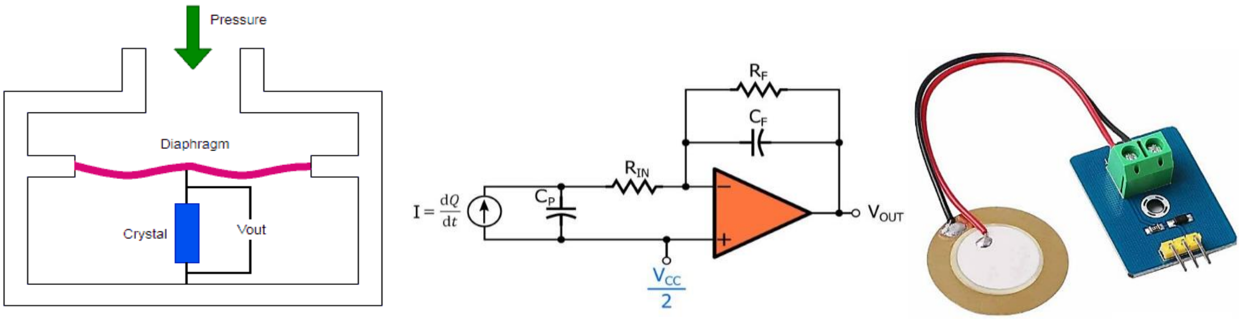


Figure 6. Schematic diagram and constructive description of the piezoelectric

a)

b)

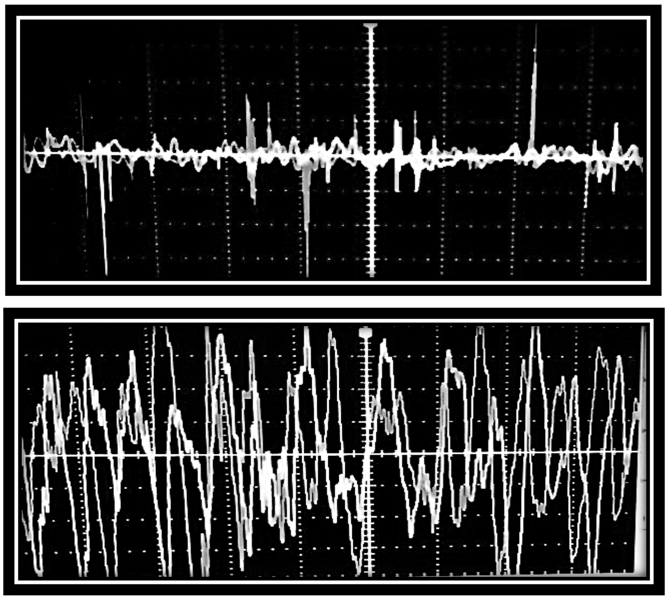


Figure 7. Oscillograms of acoustic spectra: a) during normal operation; b) in case of overload

As can be seen from the analysis of oscillograms, the fault can be detected in abnormal modes. This makes it possible to include the acoustic parameter in the proposed multi-parameter monitoring control system.

Temperature control. Temperature control is one of the main diagnostic parameters of the TEM under study. The increase in temperature may depend on several parameters: failures in the pillow, overload, cessation of ventilation, etc. Several methods are used to measure temperature. These include fiber-optic temperature sensors, electrical resistance thermometers, thermography, thermocouple-based temperature sensors, and more [12].

When the operating temperature of the motor windings exceeds the heating limit of 100 ℃ for any period of time, the service life of the stator and rotor windings is reduced by half.

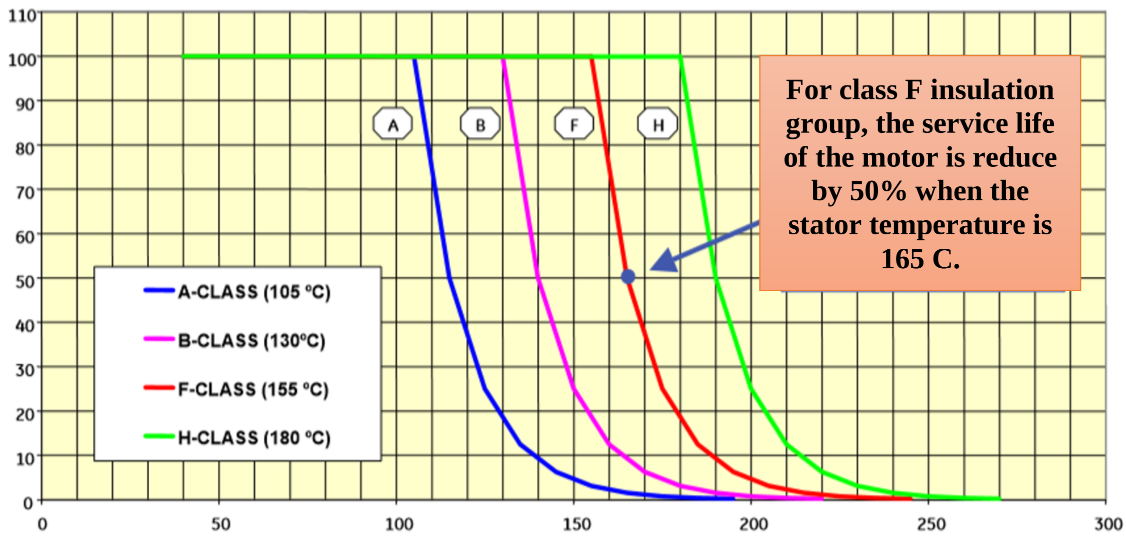


Figure 8. Temperature diagram for different insulation classes

In large-powered motors, as well as in TEM under study, the most suitable method for temperature control is the use of thermocouples. The schematic diagram and design description of the thermocouple used in the experimental studies are given in Figure 9.

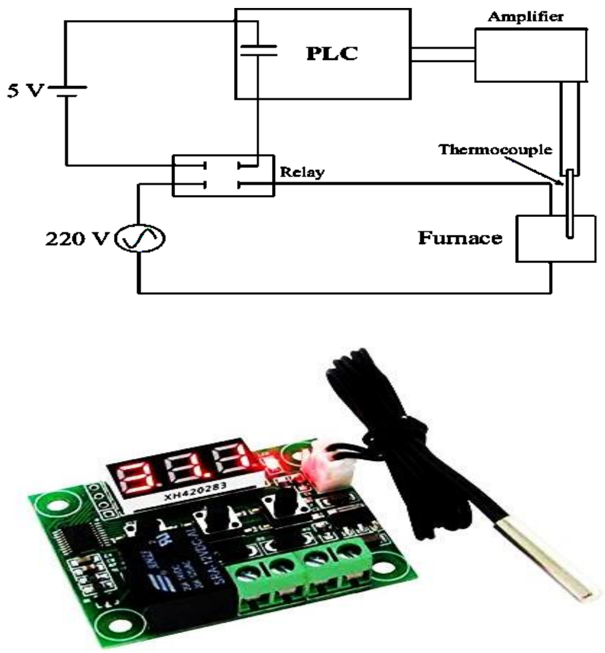


Figure 9. Schematic diagram and constructive description of the temperature sensors

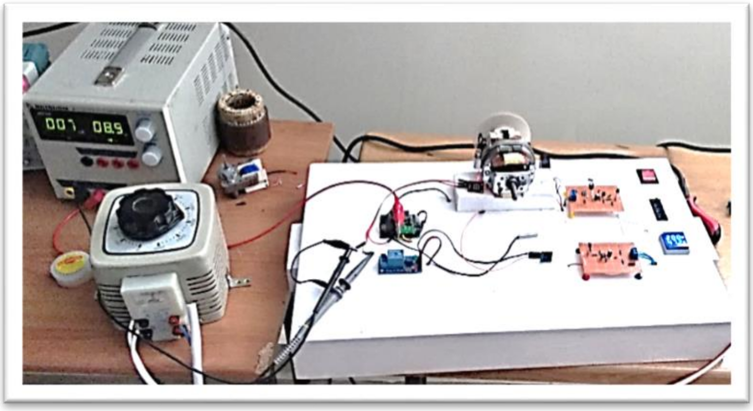


Figure 10. Imitation model of a complex diagnostic control system on a small powerful motor

CONCLUSION. Thus, while the train is in motion, it is possible to diagnose the magnetic field, temperature, sound, vibration of the windings of the TEM in parallel and transmit the results to the driver's cab and display them on the appropriate display. Based on the values of various diagnostic parameters, it is possible to draw conclusions about the technical condition of the motor and the specific failure. Thanks to the development and practical application of a complex diagnostic system for TEM, it is possible to plan repair times based on the technical condition of the motors. This will allow the traction of electric motors to be transferred from the scheduled-warning repair system to the repair system according to the technical condition. Also, with the help of a comprehensive diagnostic system, we can ensure the optimal operating conditions: reduce the cost of maintenance and inspection of TEM; Predict TEM failure and increase resource; Increase the reliability of TEM and components; Organization of direct control in the working condition without breaking the TEM into parts; Optimizing the working condition of the TEM; Improving the accuracy of TEM fault prediction.

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CHOICE OF EQUIPMENT DESIGN AND EXPLANATION OF THE PRODUCTION PROCESS FOR RAINERGY

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Annotation. It turns out that the presented technology is the most suitable technology for the relevant project. When applying this technology, there will be no major changes in the place of installation of the device, the design is simple, easy to maintain, the structural elements of the device can be replaced with other materials. It will also allow rainwater to be collected and used. The following article outlines the design concepts for the overall system of this proposed system. Construction of the prototype is ready.

Key words. Renewable energy, Rainenergy, rainwater.

RAINENERGY ÜÇÜN AVADANLIQLARIN SEÇİLMƏSİ VƏ İSTEHSAL PROSESİNİN İZAHI

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Annotasiya. Təqdim olunan texnologiya müvafiq layihə üçün ən uyğun texnologiyadır. Bu texnologiyanı tətbiq edərkən cihazın quraşdırılması yerində heç bir əsaslı dəyişiklik olmayacaq, dizayn sadədir, saxlanması asandır, cihazın struktur elementləri digər materiallarla əvəz edilə bilər. Bu, həm də yağış sularının yığılmasına və istifadəsinə imkan verəcəkdir. Aşağıdakı məqalə bu təklif olunan sistemin ümumi sistem üçün dizayn konsepsiyalarını əks etdirir. Prototipin tikintisi artıq hazırdır.

Açar sözlər. Bərpa olunan enerji, Yağış enerjisi, yağış suyu.

ВЫБОР КОНСТРУКЦИИ ОБОРУДОВАНИЯ И ОБЪЯСНЕНИЕ ПРОИЗВОДСТВЕННОГО ПРОЦЕССА ДЛЯ RAINENERGY

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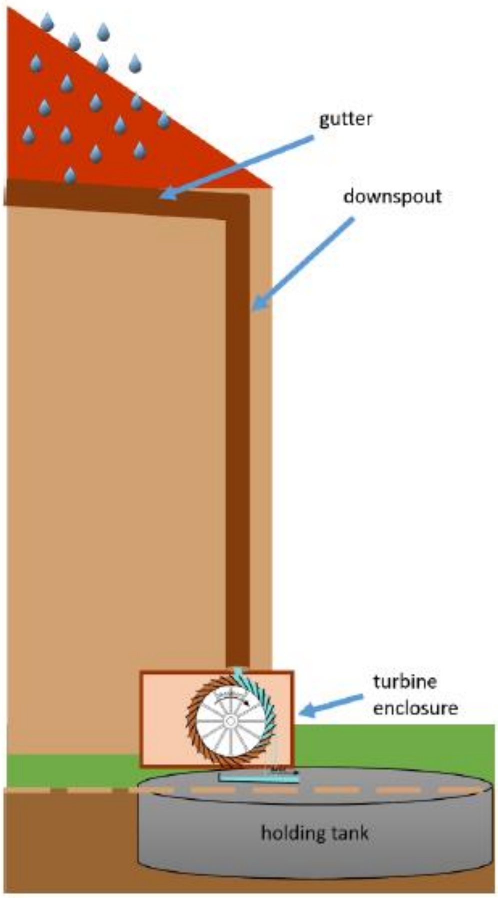
Аннотация. Представленная технология является наиболее подходящей технологией для соответствующего проекта. При применении данной технологии не произойдет серьезных изменений в месте установки устройства, конструкция проста, удобна в обслуживании, конструктивные элементы устройства могут быть заменены другими материалами. Это

также позволит собирать и использовать дождевую воду. В следующей статье излагаются концепции дизайна для всей системы этой предлагаемой системы. Конструкция прототипа готова.
Ключевые слова. Возобновляемая энергия, энергия дождя, дождевая вода.

System Components, Initial Design, and Project Scope

The system we are proposing is a dual purpose power generation and water collection. The eight components in the system and their main functions are outlined below:

1. Roof: must provide a smooth surface for water to flow down to the gutter,
2. Gutter: must be large enough to collect a significant portion of the water off the roof and angled to ensure the flow of water to the downspout,
3. Gutter-to-downspout connector: must direct the water towards the center of the downspout to minimize friction with the walls, and create a smooth stream of water,
4. Downspout: must be large enough to contain the water from the gutter and avoid backfilling,
5. Turbine/enclosure: placed at the outlet of the downspout to ensure the stream of water will strike and rotate the turbine,
6. Electrical components/enclosure: attached to the turbine shaft to produce electrical power; the enclosure will ensure the components stay dry in the wet environment,
7. Filtration system: purify the water so that it is safe to drink, and
8. Holding tank: store collected rainwater for future use [1].



Pic 1: Initial Design

Pic. 1 depicts a drawing of our initial design. The rainwater will be collected from the roof via the gutter system that will run along the perimeter of the house. The water will be directed into the downspout that leads into an enclosure with a turbine. After the water flows through the turbine, it is collected in a tank beneath the system where it will be stored and can be filtered for drinking water.

There are three components outside the scope of the project: the roof, the holding tank, and the filtration system. The system proposed begins with the roof. The roofs are made of corrugated metal.

The corrugated metal will provide a smooth surface for the water to flow down to the gutter. The roofs are also slightly angled to ensure the flow of water. The material and design of the roofs in the proposed location are already satisfactory for the system. Furthermore, the system is intended for low-income families and should not induce extraneous costs. Therefore, we will not be considering redesigning the roof for our system.

The scope of our projects is primarily focused on the conversion of rainwater into energy. Therefore, the project will focus on the gutter and downspout sub-system, the turbine and its enclosure, and the electrical components and their enclosure. We will not work to design the final components of the system, the holding tank and filtration system, as filtration techniques and holding tank have been thoroughly researched in other projects. In summary, we will work to create a well-designed system that includes a gutter, downspout, and rainwater energy generator [2].

Initial Power Calculation

Prior to making any design decisions, we calculated the maximum potential power harvestable from the system using theoretical values. We considered the system under two different scenarios: water flowing through a filled downspout and free falling water. In the first scenario, the 21 downspouts would have a nozzle at the very end immediately before the turbine to direct the stream of water on the turbine blades. The small nozzle area would cause the downspout to backfill and provide a pressure head. In the second scenario, the rainwater from the gutter would be directed to the center of the downspout with no backup. The downspout would not be filled and the water would ideally not touch the sides of the downspout. We considered both scenarios to determine which one would be the most beneficial and produce the most power.

The first scenario involves a nozzle at the end of the downspout. The small nozzle area would cause the downspout to backfill as rain continues to enter the downspout. If the downspout is filled, however, there will be frictional losses in the form of Equation 1:

$$h_l = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) \tag{1}$$

Where:

$h_l = Head\ Loss\ (m)$

$f = Friction\ Factor\ (unitless)$

$l = Length\ of\ the\ Pipe\ (m)$

$D = Diameter\ of\ Pipe\ (m)$

$V = Velocity\ Exiting\ the\ Pipe\ (\frac{\mathrm{m}}{\mathrm{s}})$

$g = Gravity\ (\frac{\mathrm{m}^2}{\mathrm{s}})$

The frictional losses will decrease the maximum velocity that exits the nozzle, and will therefore lower the power production and the RPM. Because the system is small-scale, the goal was to minimize losses as much as possible, therefore a nozzle at the end of the downspout and backfilling the downspout would not be beneficial. Rather, designing the downspout so that the water falls in a single stream down the center of the downspout to strike the blade will help to enhance the performance of the system.

In the second scenario, the water would be directed to the center of the downspout to avoid frictional losses. The calculations outlined below estimate the power production from a 20 centimeter diameter Pelton wheel for the case of free-falling water during the heaviest rain. The Pelton wheel was chosen for the calculations because the equations are well-developed and easily accessible.

The first step was to calculate the flow rate of the water off of the roof based on the roof area and rainfall intensity. The theoretical roof area used for the project was 5 meters in length by 3 meters in depth. Thus the roof area is 15 meters squared. The maximum rainfall intensity was based on 2 year characterization of rainfall data in Liberia. The maximum intensity is 272.40 millimeters per hour and occurs for 0.10 hour (6 minutes). The volumetric flow rate of the water entering the pipe is determined by Equation 2:

$$Q = A * I \tag{2}$$

Where:

$Q = Flow\ Rate\ (\frac{m^3}{s})$

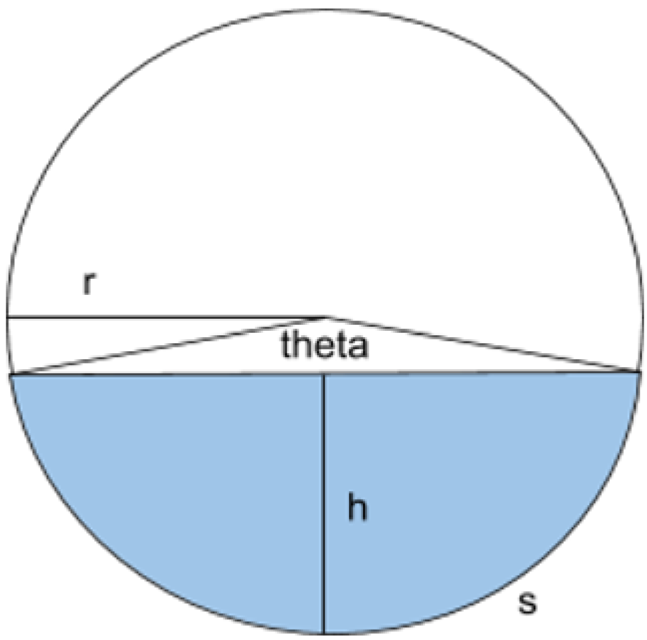
$A = Adjusted\ Area\ (m^3)$

$I = Rainfall\ Intensity\ (\frac{m}{hr})$

$Q = 15 * 0.2724 * (\frac{1}{3600})$

$Q = 0.001135(\frac{m^3}{s})\ \ or\ (17.99\ (\frac{\text{gallons}}{\text{minute}})$

A standard half round painted aluminum gutter from Home Depot will be used as a theoretical gutter for the purposes of the calculations. The gutter has a diameter of 12.7 centimeters (5 inches). The length of the gutter is the length of the roof: 5 meters. A typical gutter slope is 1%. The manning resistance coefficient, n, is 0.014 for painted metal (Munson et al., 2013, pg. 569). We assumed that the filled height was about 75% of the radius in order to perform the calculations, so the height was 4.76 centimeters. The area and wetted perimeter can be found by calculating the circular segment area and arc length of the circular segment filled by the water, respectively, shown in Pic. 2, to find the arc length we need to know theta, calculated appropriate equation.



Pic. 2: Circular Segment Filled by Water

$$\theta = 2.63\ radians$$

Knowing theta, we could find the arc length, which is the wetted perimeter using Equation 5:

$$P = r*\theta \quad (5)$$

$$P = 6.35*2.63$$

$$P = 16.74\ cm = 0.1674\ m$$

The circular segment area is given by Equation 6:

$$A = 4.3*10{-}3\ \ m2 \quad (6)$$

Therefore, the velocity is:

$$V = 0.622(\frac{m}{s})$$

To be conservative in our estimates, and because the open channel flow calculations proved the velocity of the water the gutter to be small, we neglected this velocity and only considered the potential energy of water at the top of the downspout. Assuming all of the potential energy from the height of the water is converted into kinetic energy, the velocity of the water exiting the pipe is found using Equation 7:

$$V = \sqrt{2gh} \quad (7)$$

Where:

$$V = Velocity\ Exiting\ the\ Pipe\ (\frac{m}{s})$$

$$g = Gravity\ (\frac{m^2}{s})$$

$$h = Height\ of\ the\ Gutter\ (m)$$

The height of the roof is estimated to be 3 meters above the ground due to standard ceiling heights. Thus the velocity of water exiting the downspout is:

$$V = \sqrt{2 * 9.8 * 3}$$
$$V = 7.67\ (\frac{m}{s})$$

The maximum power for a Pelton wheel is modeled by Equation 8:

$$P = \rho QU(U - V)(1 - cos\beta) \qquad (8)$$

Where:

$$P = Power\ (W)$$
$$\rho = Density\ of\ Water\ (\frac{m}{s})$$
$$Q = Flow\ Rate\ (\frac{m^3}{s})$$
$$U = Blade\ Speed\ (\frac{m}{s})$$
$$V = Velocity\ Exiting\ the\ Pipe\ (\frac{m}{s})$$
$$\beta = Exit\ Angle\ of\ the\ Blade\ (Degrees)$$

Beta is the exit angle of the blade. Ideally, the water would exit at a 180 degree angle. However, this is not physically possible as the exiting water would collide with the entering water. It has been determined that an exit angle of 165 degrees is optimal.

U is the blade speed. At maximum power, the optimal blade speed is one half of the water velocity. Replacing U with ½ V, the power produced by the Pelton wheel can be calculated in Equation 9:

$$P = \rho Q(V/2)((V/2) - V)(1 - \cos\beta) \qquad (9)$$

$$P = 1000 * 0.001135 * (7.67/2) * ((7.67/2) - 7.67) * (1 - \cos(165))$$
$$P = 32.82\ W$$

The above calculations estimated the maximum potential power for a theoretical house with a roof area of 3 meters by 5 meters and a height of 3 meters at a rainfall intensity of 272 millimeters per hour.

The same calculations were completed to estimate the maximum potential power we would be able to produce in laboratory testing. The prototype system has a height of 2 meters. The maximum potential power for both the theoretical house and our prototyped system is plotted

against the rainfall intensity in Figure 12. As a note, the maximum flow rate from the hose is 8 GPM, corresponding to a rainfall intensity of 120 millimeters per hour.

Therefore, the maximum potential power output from the turbine in our prototype is approximately 10 Watts.

A 272 millimeter per hour rainfall intensity would last six minutes, from this peak storm the energy harvested would be calculated in Equation 10:

$$E = P * t \qquad (10)$$

Where:

$E = Energy\ (J)$

$P = Power\ (W)$

$t = Time\ that\ the\ Strom\ Lasts\ (seconds)$

$E = 32.82 * 360$

$E = 11815\ J$

A cell phone battery charge requires about 20,000 Joules (assuming cell phone battery holds 5.45 watt hours) and lighting one LED for one hour requires 36,000 Joules (assuming 10 W light bulb), the energy can be put into perspective by Equation 11 and Equation 12:

$Number\ of\ Cell\ Phones = Energy\ /\ Energy\ per\ Charge$ (11)

$Number\ of\ Cell\ Phones = 11815\ /\ 20000$

$Number\ of\ Cell\ Phones = 0.59$

$Number\ of\ Light\ Hours = Energy\ /\ Energy\ per\ Charge$ (12)

$Number\ of\ Light\ Hours = 11815\ /\ 36000$

$Number\ of\ Light\ Hours = 0.33$

Over the course of the day the rainfall intensity would vary, this is just the cell phone charges and light-hours from a short 6 minute storm. Depending on the rainfall more power may be generated over the course of an entire day.

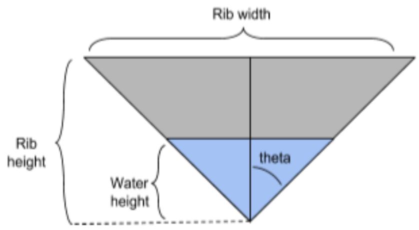
Gutter and Downspout Sub-System

The gutter and downspout sub-system includes the gutter, the gutter-to-downspout connector, and the downspout itself. This article outlines the calculations, considerations, and tests to determine the gutter sizing and slope, the preferred gutter-to-downspout connection, and the downspout design to develop a final design for the sub-system.

Gutter Sizing and Slope Sizing the gutter to contain the water coming off the roof was the first step of designing this sub-system. The gutter sizing calculations were completed using two approaches. The first approach determines the velocity and projection of the water coming off the roof to determine the necessary width of the gutter.

First, the Manning equation was used to determine the water depth in each roof corrugation during maximum rainfall. Again, the maximum rainfall intensity of 272.40 millimeters per hour in 0.10 hours was used. The roof area of 15 meters squared, was also used. We chose this rainfall intensity as it provided us with a maximum flow rate, and therefore maximum velocity and displacement off the roof to calculate a gutter that was a sufficient size for most rainfall conditions. Next the roof corrugations needed to be considered. One standard corrugation is triangular, with a rib width of 63.5 millimeters and rib height of 12.7 millimeters. The corrugations are estimated to

be triangles connected at the vertices directly next to each other [3]. A single roof corrugation is shown in Pic. 3.



Pic. 3: Depiction of Single Corrugation

Pic. 4: Gutter and Downspout of Rainenergy (Lankaran district, Dashdatuk village)

To determine the most suitable gutter-to-downspout connection, we conducted preliminary testing of connections: vertical downspout (Pic. 4) [4].

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As the youngest female entrepreneur in the Global Entrepreneurship Summit India in 2017, her work was acknowledged by Ivanka Trump, who repeated her motto “Light up one house at a time” on stage to thousands of people.

As a result of Rainenergy’s success, Reyhan was selected for the Forbes 30 Under 30 List in Asia as the first Azerbaijani, placed on BBC’s 100 Most Influential and Inspiring Women List of 2018, and invited to international conferences as a keynote speaker. Reyhan is a 2018 Presidential Youth Award holder, 2019 TRT World Youth Award winner, the Global Good Fund 2020 Fellow, bp NetZero Scholar, and One Young World Ambassador.

In addition to bettering the lives of many struggling families with Rainergy, Reyhan convinced the people in her country to believe in their daughters’ potential, worth and dreams with her own accomplishments.

CHEMICAL COMPOSITION OF GEOTHERMAL WATERS OF YARDYMLI DISTRICT OF AZERBAIJAN

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Abstract: Chemical composition of eight geothermal water samples from south-east of Azerbaijan (Yardymli region: Arus, Alibad, Peshtasar, Shalala, Mirzhekhan, Sougbulag, Korbulag, and Bagbulag) studied in this work. A IRIS Intrepid II Optical Emission Spectrometer (cations) and Ion Chromatograph (anions) techniques were used to quantitative determination of the elemental composition in the geothermal water samples.

Key words. Geothermal water, chemical composition, spectrometer, cation, anion.

ХИМИЧЕСКИЙ СОСТАВ ГЕОТЕРМАЛЬНЫХ ВОД ЯРДЫМЛИНСКОГО РАЙОНА АЗЕРБАЙДЖАНА

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Аннотация: В данной работе изучен химический состав восьми проб геотермальных вод с юго-востока Азербайджана (Ярдымлинский район: Арус, Алибад, Пештасар, Шалала, Мирзехан, Союгбулаг, Корбулаг, Багбулаг). Для количественного определения элементного состава в пробах геотермальных вод использовались методы оптического эмиссионного спектрометра IRIS Intrepid II (катионы) и ионного хроматографа DX 100 (анионы).

Ключевые слова: Геотермальная вода, химический состав, спектрометр, катион, анион.

AZƏRBAYCANIN YARDIMLI RAYONUNUN GEOTERMAL SULARININ KİMYƏVİ TƏRKİBİ

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Xülasə: Bu işdə Azərbaycanın cənub-şərqindən (Yardımlı rayonu: Arus, Əlibad, Peştəsər, Şələlə, Mirzəxan, Soyuqbulaq, Körbulaq, Bağbulaq) səkkiz geotermal su nümunəsinin kimyəvi tərkibi tədqiq edilmişdir. Geotermal suların nümunələrində elementar tərkibinin kəmiyyətcə müəyyən edilməsi üçün IRIS Intrepid II optik emissiya spektrometrinin (kationların) və DX 100 ion xromatoqrafın (anionların) üsullarından istifadə edilmişdir.

Açar sözlər: Geotermal su, kimyəvi tərkib, spektrometr, kation, anion.

Introduction: As natural water flows through the ground, natural and human-induced (from leaking fuel tanks or toxic chemical spills) chemicals (iron and manganese, for example) can be found in high concentrations. Industrial discharges, urban activities, agriculture, groundwater pumpage, and disposal of waste all can affect natural waters quality and their chemical contents,

consequently and their properties. It is apparent that relationship between environmental factors (rainfall, agricultural and urbanrunoff, evaporation, regional climate, municipal and industrial treated wastewater) and natural waters composition is influencing on their properties and qualities. Also, the chemical composition of natural water is derived from main different sources, including weathering and erosion of rocks and soil, solution and precipitation reactions occurring underground. The chemical composition of the crustal rocks of the Earth and the composition of the ocean and the atmosphere are significant in evaluating sources in natural freshwater. Pesticides and fertilizers applied to lawns and crops can accumulate and migrate to the water table [1]. The chemical characteristics of natural water are a reflection of the soils and rocks with which the water has been in contact. The quality of the natural waters also has human health effects [2]. For example, high sodium content (when above contaminant level) in natural water can be a health risk factor for those individuals on a low-sodium diet. Nitrate occurs naturally in mineral deposits, soils, seawater, freshwater systems, the atmosphere, and biota. Toxicity (results from the body's natural breakdown of nitrate to nitrite), causes methemoglobinemia, which threatens oxygen-carrying capacity of the blood [2]. Presence of hazardous or toxic organic materials in water is unfitting to drink, even though the water may be safe for public use. The increase concentration of the sulfates anions (SO_4^{2-}), at one hand brings about change for the worse of some physical characteristics of water (taste, smell and etc.) and on the other hand has destructive influence upon human consumption [2]. Sulfate elevated concentrations may result from saltwater intrusion, mineral dissolution, and domestic or industrial waste, forms hard scales on boilers and heat exchangers; can change the taste of water, and has a laxative effect in high doses [3].

During the period of contact with rocks and soils the water dissolves inorganic minerals, which enter the natural waters. Inorganic compounds may dissociate to varying degrees, to cations and anions. Major cations found in natural water include calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^+) and potassium (K^+). Calcium (Ca^{+2}), is the most prevalent cation in water and second inorganic ion to bicarbonate in most surface water. The principal concern about calcium is related to the fact that calcium is the primary constituent of water hardness. Calcium precipitates as $CaCO_3$ in iron and steel pipes. A thin layer of $CaCO_3$ can help inhibit corrosion of the metal. However, excessive accumulation of $CaCO_3$ in boilers, hot water heaters, heat exchangers, and associated piping affects heat transfer and could lead to plugging of the piping. Calcium concentrations of (40 to 120) mg/L in natural waters are more common. In our natural water samples the calcium content is within (83 to 197) mg/L. Magnesium is not abundant in rocks as calcium. Although magnesium salts are more soluble than calcium, less magnesium is found in natural water. In the present natural waters the magnesium ions content is within (19.7 to 100) mg/L, while sodium (from 26.4 to 159 mg/L) and potassium (from 0.63 to 14.5 mg/L) are commonly found as free ions.Major anions include chloride (from 3.5 to 58.7 mg/L), sulfate (from 27.2 to 642.0 mg/L), and nitrate (from 1 to 207.5 mg/L). Anions such as chlorides (Cl^-), sulfates (SO_4^{-2}), and nitrates (NO_3^-) are commonly found in natural water. These anions are released during the dissolution and dissociation of common salt deposits in geologic formations. The concentration of the chlorides anions (Cl^-) determines the water quality because the quality of water get worse after increasing in the concentration of this anions which limit possibilities of using of natural water for different purposes (household, agriculture, industry and etc.). Principal source of the chlorides

anions (Cl^-) in natural water are magmatic rock formations that include chlorine-content minerals. The second source of this anions is Ward Ocean from where a considerably amount of chlorides anions (Cl^-) enter in the atmosphere. From atmosphere chlorides anions (Cl^-) enter in the natural water in result of interaction between precipitation and soil. The sulfates anions (SO_4^{-2}) are frequently found in natural water as the result of the chemical dissolution dissolve sulfur-content minerals and oxidize sulfates and sulfur. The sulfates anions (SO_4^{-2}) enter in natural water as the result of the oxidation of the substances from plant and animal origin. The concentration of the sulfates anions (SO_4^{-2}) fluctuates in a wide range in surface water (from 5to 60 mg/L).In our natural water samples sulfates anions content is within from (27.2 to 642) mg/L. Nitrate anions (NO_3^-) are found in natural water as the result of the bacteriological oxidation of nitrogenous materials in soil. That is why the concentration of these anions rapidly increases in summer when the process of the nitrification takes place very intensively. Another important source for dressing of the surface water with nitrate anions (NO_3^-) are precipitations, which absorb nitric oxides and convert them into nitric acid. A great deal of nitrate anions (NO_3^-) enters in natural water together with domestic water and water from industry, agriculture and *etc*. Nitrate anions (NO_3) are one of the indicators for the degree of the pollution with organic nitrate-content substances. Presence of nitrates in the present natural water samples is within from (0.8 to 207.7) mg/L.

Geothermal Field Location: The natural water samples for the present study come from south-east of Azerbaijan (Yardymli Districtwells: Arus, Alibad, Peshtasar, Shala, Mirzhekhan, Sougbulag, Korbulag, and Bagbulag). The geographical location of the geothermal area (geothermal wells) where the natural water samples come from is presented in Table 1.

Table 1. Geographical location of the geothermal area (geothermal wells) of south-east of Azerbaijan, (Yardymli District) where the natural water samples come from

Arus	**Aliabad**	**Peshtasar**	**Shalala**
38°55'40"North 48°14'47"East	38°56'18" North 48°15'17" East	38°49'53" North 48°12'06" East	38°56'38" North 48°26'52" East
Mirzakhan	**Sougbulag**	**Korbulag**	**Bagbulag**
38°55'50" North 48°27'42" East	38°56'13" North 48°13'12" East	38°53'56" North 48°06'47" East	38°59'03" North 48°24'39"East

The economic activities of the region include agricultural products. This region is commonly known for its rich natural surface geothermal and natural mineral springs. This indicates that larger scale hydrothermal hot and mineral sources may exist in the subsurface. The hot geothermal brines produced from the well (Peshtasar) have the potential for possible district-usage applications for surrounding communities. Currently the geothermal and natural waters from the wells are basically using for healing purposes, as a mineral drinking natural waters and hot bathing. Geothermal brines from the well (Peshtasar) are used in direct uses like greenhouse heating, hot bathing, sauna bathing, space heating (building and districts), heating hotels and private houses, schools, hospitals, kindergartens, uncovered aquaculture ponds, fruits or crops drying, skin healing, aching muscles, and rushes, *etc*. The minerals (like silica and sulphur) and salts from the geothermal brines are creating the beneficial effects. The geothermal hot water produced from the well Peshtasar is using partly in the Geothermal Health Spa and for sauna, spa, and healing pools. Balneology is a medical

practice of soothing aching muscles practiced in hot springs and health spas. Also, the minerals and salts from the natural waters are create the beneficial (health effect) effects, help people suffering from various diseases.

Results and Discussion: As well-known the thermophysical properties of natural waters are strongly affected by their chemical composition. Natural geothermal fluids are responsible for mobility and transport of inorganic and organic solid and liquid phases and gaseous nonelectrolytes. The composition of a particular well varies as a function of the total production time, the rate of flow, and the nature of the underlying sediments. Thus, the natural water compositions is varying from well to well, depending on the depth of production and the temperature of the different parts of the reservoir due to precipitation some component (effect of phase-equilibrium behavior of brine). Therefore, chemical contents of the natural geothermal fluids from various wells are different and their properties will also vary. Table 2 lists, in mg/*L*, the composition of eight natural water samples from south-east of Azerbaijan (Yardymli region: Arus, Alibad, Peshtasar, Shalala, Mirzhekhan, Sougbulag, Korbulag, and Bagbulag) studied in this work. A IRIS Intrepid II Optical Emission Spectrometer and Ion Chromatograph techniques were used to quantitative determination of the elemental composition (cations and anions) in the natural water samples. Accuracy was 0.2 % to 1.0 %.

Table 2. Chemical compositions of the geothermal waters from south-east of Azerbaijan Geothermal Field (Yardymli District)

Species (*mg*/*L*)	**Arus**	**Aliabad**	**Peshtasar**	**Shalala**	**Mirzakhan**	**Sougbulag**	**Korbulag**	**Bagbulag**
Cations								
Al	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
As	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B	<0.01	<0.01	7.04	<0.01	0.06	<0.01	<0.01	<0.01
Ba	0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ca	159	197	91.3	83.1	85.3	103	69.6	91.4
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
K	5.28	3.97	0.63	3.20	14.5	9.19	1.40	2.46
Li	0.02	0.05	0.12	0.01	0.05	0.03	0.02	0.02
Mg	27.4	45.5	100	19.7	36.9	22.7	19.9	26.6
Mn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mo	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Na	32.7	90.4	159	26.4	48.8	30.1	27.0	26.4
Ni	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

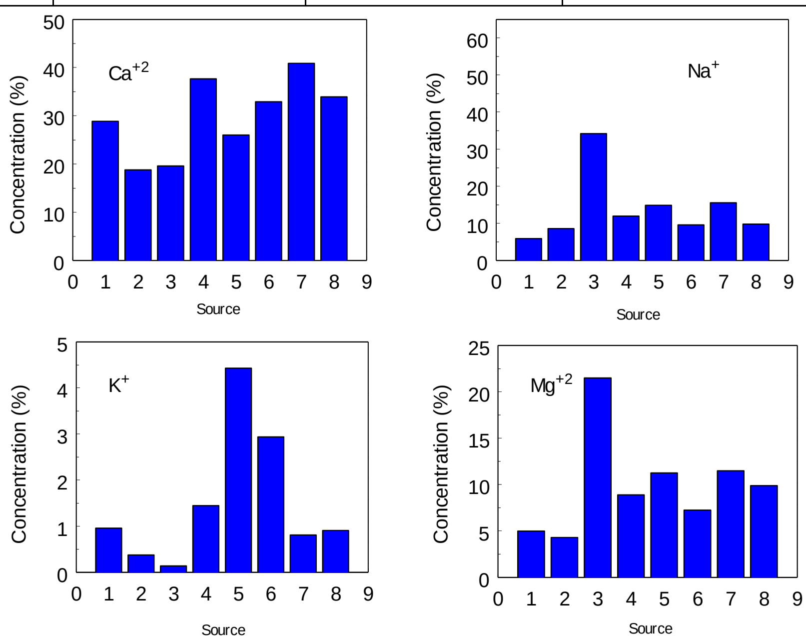
P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
S	5.2	51.3	4.58	6.71	10.7	6.47	2.98	5.27
Sb	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Se	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Si	6.16	4.61	41.5	4.74	6.37	4.74	4.29	5.59
Sn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ti	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
V	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total dissolved Cations	**236.09**	**392.89**	**404.22**	**143.91**	**202.73**	**176.28**	**125.25**	**157.79**
	Anions							
Chloride	58.7	10.7	15.6	9.1	8.1	10.2	3.5	19.0
Nitrate	207.5	1.0	0.80	3.0	6.4	65.1	17.1	42.6
Sulfate	47.3	642.0	44.5	64.5	110.2	61.2	27.2	49.9
Total dissolved Anions	**313.5**	**653.7**	**60.9**	**76.6**	**124.7**	**136.5**	**47.8**	**111.5**
Total dissolved salts	**549.59**	**1046.59**	**465.12**	**220.51**	**327.43**	**312.78**	**173.05**	**269.29**

The elements are ionized in the plasma flame of argon plasma and analyzed by a high resolution mass spectrometer. As one can see from Table 2 the mineralization of the natural water samples are (mg/*L*): Arus-549.59, Alibad-1046.59, Peshtasar-465.12, Shala-220.51, Mirzhekhan-327.43, Sougbulag-312.78, Korbulag-173.05, and Bagbulag-269.29 9. Based on the data from Table 2, the chemical composition concentration distributions by wells and chemical species are depicted in Figs. 1 and 2. As one can note from Table 2, the main components of the present natural water samples are (see also Table 3): **Arus**- Calcium (28.9 %) and Nitrate (37.8 %); **Aliabad**- Calcium (18.8 %) and Sulfate (61.3 %); **Peshtasar**- Calcium (19.6 %), Sodium (36.2 %), Magnesium (21.5 %), and Sulfate (9.6 %); **Mirzakhan**- Calcium (26.1 %), Sodium (14.9 %), Magnesium (11.3 %), and Sulfate (33.7 %); **Sougbulag-** Calcium (32.9 %), Sodium (9.6 %), Magnesium (7.3 %), Nitrate (20.8 %), and Sulfate (19.6 %); **Shalala**- Calcium (37.7 %), Sodium (12.4 %), Magnesium (8.9 %), and Sulfate (29.1 %); **Korbulag-** Calcium (40.2 %), Sodium (15.6 %), Magnesium (11.5 %), Nitrate (9.9 %), and Sulfate (15.7 %); **Bagbulag-** Calcium (33.9 %), Sodium (9.8 %), Magnesium (9.9 %), Nitrate (15.8 %), and Sulfate (18.5 %). Therefore, the major mineral components in the natural water samples under studied are: Calcium within (18.8 to 40.2 %), Sodium within (5.9 to 34.2 %); Magnesium within (4.3 to 21.5 %); Nitrate within (0.1 to 37.8 %); and Sulfate within (8.6 to 61.3 %). The dissolved cations of (SO_4^{-2}) were found in significant quantities (61.3 %) in the sample from Aliabad, while more Ca^{+2} (40.2 %) and Mg^{+2} (21.5 %) were found in the samples from

Korbulag and Peshtasar, respectively. The Na^+ content in the sample from Peshtasar 34.2 % was much higher than in other sources. Highest content of nitrates (37.8 %) was found in the sample from Arus. The natural water samples were collected at about ambient temperature (except the sample from Pashtasar hot-well which temperature on the surface was 45 ºC), filtered to remove suspended solids.

Table 3. Chemical composition distributions for natural water samples from south-east of Azerbaijan Geothermal Field (Yardymli District)

Species	**Arus, (%)**	**Aliabad, (%)**	**Peshtasar, (%)**	**Mirzakhan, (%)**
Calcium	28.9	18.8	19.6	26.1
Potassium	1.0	0.4	0.1	4.4
Magnesium	5.0	4.3	21.5	11.3
Sodium	5.9	8.6	34.2	14.9
Sulfur	0.9	4.9	1.0	3.3
Si	1.1	0.4	8.9	2.0
Chlorine	10.7	1.0	3.4	2.5
Nitrate	37.8	0.1	0.2	2.0
Sulphate	8.6	61.3	9.6	33.7
Species	**Shalala, (%)**	**Sougbulag, (%)**	**Korbulag, (%)**	**Bagbulag, (%)**
Calcium	37.7	32.9	40.2	33.9
Potassium	1.5	2.9	0.8	0.9
Magnesium	8.9	7.5	11.5	9.9
Sodium	12.4	9.6	15.6	9.8
Sulfur	3.0	2.1	1.7	2.0
Si	2.2	1.5	2.5	2.1
Chlorine	4.1	3.3	2.0	7.1
Nitrate	1.4	20.8	9.9	15.8
Sulphate	29.1	19.6	15.7	18.5



Composition Diagram

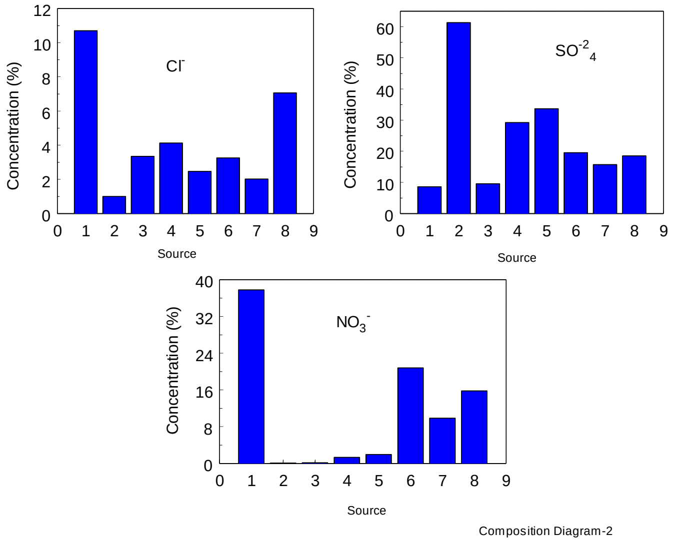


Fig. 1. Chemical composition (main anions and cations) concentration distributions for natural water samples from the various sources by sources (wells). 1- Arus; 2-Aliabad;3-Peshtasar;4- Shalala; 5-Mirzekhan;6- Sougbulag;7- Korbulag; and 8- Bagbulag.

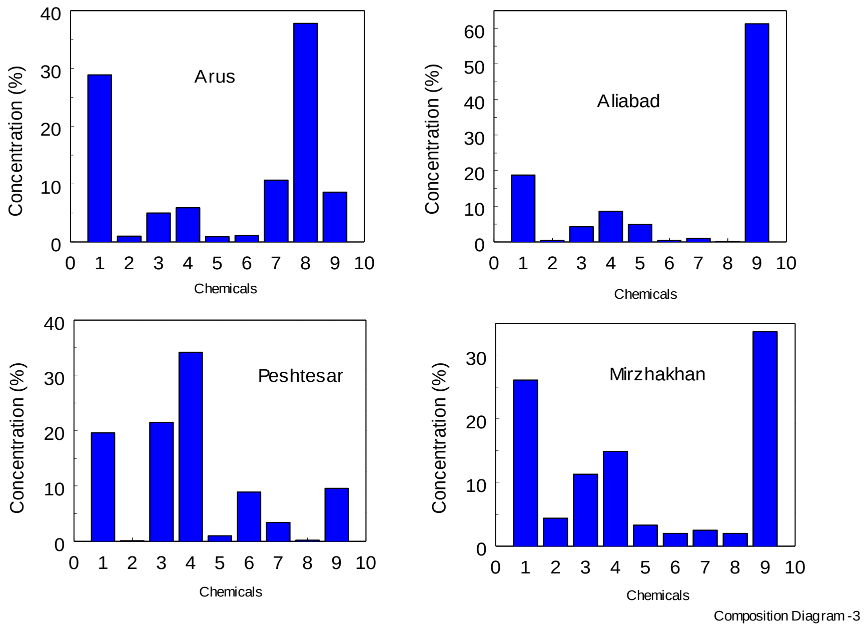


Fig. 2. Chemical composition (main anions and cations) concentration distributions for natural water samples from the various sources by chemicals. 1- Calcium; 2-Potassium;3-Magnesium;4- Sodium; 5-Sulfur;6- Silicium;7- Chlorine; 8- Nitrate; and 9-Sulphate.

Conclusions: It is apparent that there is direct relationship between the quality (chemical content) and the physicochemical properties of natural waters. Usually, fundamental data used in the determination of water quality are obtained by chemical analysis of water samples in the laboratory.

As well-known, the properties of aqueous salt solutions considerable depend on their composition and of the chemical nature of their compents, i.e. very sensitive on the chemical structure. Some type of chemicals is strongly affecting on properties their aqueous solutions, i.e., depends on their chemical nature.

The study of the time-dependence of the concentration changes in natural water showed that the composition of the natural water from the same source changes with using time. In addition, different compounds with various chemical structures can be formed during the use that might considerable change the properties of the natural water.

Therefore, the progress of the natural water quality changes can be monitored by controlling the density and vapor-pressure of natural water based on the compositional changes [4]. Since natural water is a mixture of various salts which each component contributing to the total measured properties, it is apparent that there is strong correlation between the properties of natural water and specific chemicals content.

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SMALL WIND TURBINE TECHNOLOGY

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Annotation: This article provides a comparative analysis of various types of small turbine technologies. The technical characteristics of the turbines are given. The turbine's energy production was calculated by measuring the wind potential in the area. At different wind speeds, power curves and turbine power generation were calculated. Applications for small wind turbines are reported.
Keywords: small, turbine, wind, vertical, horizontal, generator

Kiiçik turbin texnalogiyaları

Məmmədov R.R

Annatasiya: Bu məqalədə kiçik turbin texnalogiyalarının müxtəlif növləri arasında müqaisəli analiz aparılmış. Turbinlərin texniki göstəriciləri verilmiş və külək potensialı ölçməklə ərazidə turbindən alınacaq enerji hesablanmışdır. Fərqli külək sürətlərində turbinlərin güc əyrisi və enerji istehsalı göstərilmişdir.

Açar sözlər: kiçik, turbin, mühərrik, vertikal, horizontal, külək

Малых турбинных технологий

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Аннотация: В данной статье проводится сравнительный анализ различных типов малых турбинных технологий. Приведены технические характеристики турбин. Производство энергии турбиной было рассчитано путем измерения ветрового потенциала в этом районе. При различных скоростях ветра были рассчитаны кривые мощности и выработка электроэнергии турбинами. Сообщается о сферах применения малых ветряных турбин.

Ключевые слова: малая, турбина, двигатель, вертикаль, горизонталь, ветер

Introduction. The power generation principle of small wind turbines mainly uses the wind energy of the natural environment. Wind is created by the unequal heating of the Earth's surface by the sun. Wind turbines convert the kinetic energy in wind into mechanical power that runs a generator to produce clean electricity. Today's turbines are versatile modular sources of electricity. Their blades are aero- dynamically designed to capture the maximum energy from the wind. The wind turns the blades, which spin a shaft connected to a generator that makes electricity.

The form of small wind turbines can be divided into horizontal axis (Horizontal Axis) and vertical axis (Vertical Axis) two types [Figure 1].

Horizontal-axis wind turbines have fast rotation speed and high noise, but the power generation coefficient is large. The power generation environment needs to be set up in a wind field environment with an annual average of 5 m/s to 15 m/s in order to have the best power generation. efficacy. The vertical axis wind turbine has slow speed and low noise, but the power coefficient of power generation is also smaller than that of the horizontal axis wind turbine. Because of the characteristics of slow speed and low noise, there are relatively few restrictions on the installation location, and it can be started at low wind speeds. The total power generation in the low average wind speed area is better than the horizontal axis type. If the vertical axis type and the horizontal axis type are compared with each other, the advantages and disadvantages can be summarized as follows:

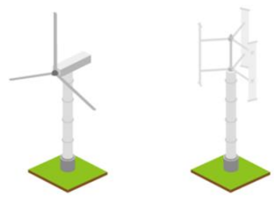


Figure1

Vertical axis small wind turbine It is not affected by the turbulent flow of the environment and terrain, and is less affected by the variation of the environment and terrain of each site. It can solve the terrain wind problem and is suitable for buildings with many obstacles (such as high-rise buildings and urban areas) Assuming that there are few restrictions on height and accuracy, DIY can be easily popularized

Start at low wind speed
Wind power is low in efficiency, but produces less noise
Integrated mains parallel technology, applicable to various occasions

Horizontal small wind turbine Integrated and applied to buildings with good wind conditions and stable conditions with few obstacles
The speed is too fast and the noise is high
The distance between the fans is longer, and the setting restrictions are more

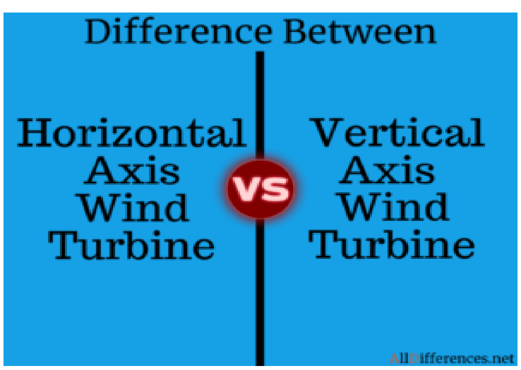


Figure 2

Difference Between Horizontal and Vertical Axis Wind Turbine [Figure 2].

Comparison Between Horizontal and Vertical Axis Wind Turbine. The Major Difference Between Horizontal and Vertical Axis Wind Turbine is that In the Vertical Axis Wind Turbine rotation of blades is Vertical and In Horizontal Axis Wind Turbine rotation of blades is Horizontal. The usual images of turbines with three blades spinning is a Horizontal Axis Wind Turbine

Comparison Chart

Horizontal Axis Wind Turbine	Vertical Axis Wind Turbine
Axis of rotation is parallel to the air stream	Axis of rotation is perpendicular to the air stream.
Yaw control mechanism is required to adjust the rotor around a vertical axis to keep it facing the wind.	No orientation of rotor is required; these turbines can generate power with the wind coming from any direction.
The heavy nacelle containing the gearbox, generator, etc. is mounted at the top of the tower, thus the design and installation is complex.	The nacelle is not required because the gearbox, generator, etc., are located at the ground, thus the design and installation are simple.
The power coefficient and tip speed ratio are high.	The power coefficient and tip speed ratio are considerably low.

How to Calculate Wind Energy. Wind is made up of moving air molecules which have mass - though not much. Any moving object with mass carries Kinetic Energy in an amount which is expressed by the equation:
Kinetic Energy = 0.5 x Mass x Velocity^2

$$m = \rho V = \rho \cdot Avt = \rho \cdot \pi r^2 vt$$

Where the mass is measured in kg, the velocity in m/s, and the kinetic energy is given in joules. Air has a known density (around 1.23 kg/m^3 at sea level), so the mass of air hitting a wind turbine (which sweeps a known area) each second is given by the following equation:

Mass/sec (kg/s) = Velocity (m/s) x Area (m^2) x Density (kg/m^3)

$$E_{kin} = \frac{1}{2} m \cdot v^2 = \frac{\pi}{2} \rho r^2 t \cdot v^3$$

Therefore, the power (i.e. energy per second) in the wind hitting a wind turbine with a certain swept area is given by simply inserting the Mass/sec calculation into the standard kinetic energy equation given above, resulting in the following vital equation:
Power = 0.5 x Swept Area x Air Density x Velocity^3

$$P_{Wind} = \frac{E_{kin}}{t} = \frac{\pi}{2} \rho r^2 \cdot v^3$$

Where power is given in watts (i.e. joules/second), the swept area in square metres, the Air Density in kilograms per cubic metre, and the velocity in metres per second.

How to Calculate Air Density. The evaluation of the air density is essential for wind measurements, as the air density varies largely on different levels and degrees. The air pressure difference between – 10° C and +30° is 0.177 kg/m3.
Air Density is:

$$\rho = \frac{p}{R \cdot T}$$

in kg/m^3; air pressure = p, gas constant R, temperature in Kelvin = T

What is the Measuring Unit for Wind Energy. Wind energy is measured in kilowatt hours (kWh) or megawatt hours (MWh), plus the time period, e.g. per year and per hour.

Wind Measurement Knowledge. Would be better to measure the local wind conditions are measured to perform a de-tailed wind site assessment. For this purpose, a wind measuring observation station should be installed and measurements should be made with high-class sensors.

Figure 3

Horizontal Axis Wind Turbine (HAWT)

- Horizontal axis machines have emerged as the most successful type of turbines. These are being used for commercial energy generation in many parts of the world.
- They have low cut-in wind speed, easy furling and, in general, show a high power coefficient.
- However, their design is more complex and expensive as the generator and gearbox are to be placed at the top of the tower. Also, a tailor yaw drive is to be installed to orient them in the wind direction. [Figure3]
- **Main components:**

1	Turbine blades	5	Generator
2	Hub	6	Yaw control
3	Nacelle	7	Brakes
4	Power transmission system	8	Tower

Vertical Axis Wind Turbine (VAWT)

- Vertical axis wind turbine (VAWT) is also known as cross-wind axis machines.
- In these machines, the axis of rotation is perpendicular to the direction of the wind.
- The main **advantages of a VAWT compared to HAWT** are
- The vertical axis wind turbine receives wind from any direction, and hence the yawing system is not required.

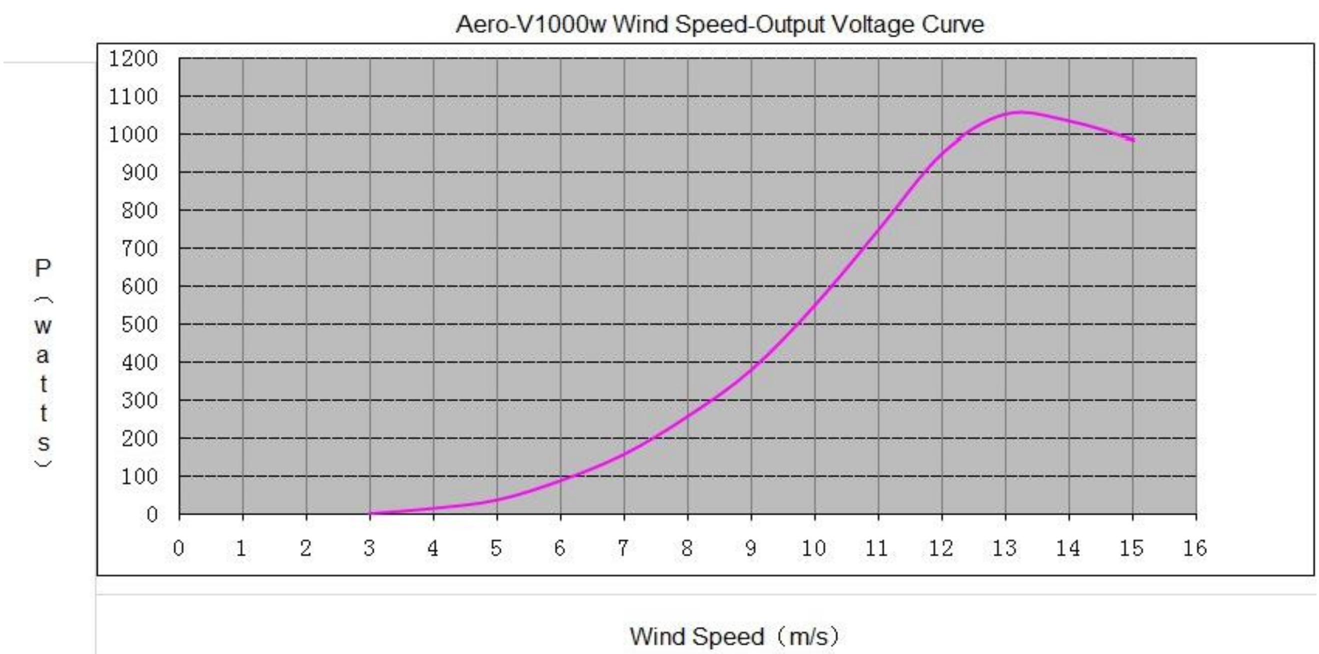
- The generator, gearbox, etc. can be installed at the bottom of the tower, hence their tower design and installation is simple. [Figure 4]
- Inspection and maintenance is easier.
- They are lighter in weight and cheaper in cost.
- VAWTs are generally not self-starting and have a low power coefficient, these are the major disadvantages. They require a mechanism to start from the stationary position. Additionally, there is a possibility of running the blades at a very high speed and causing damage to the system.

Figure 4.

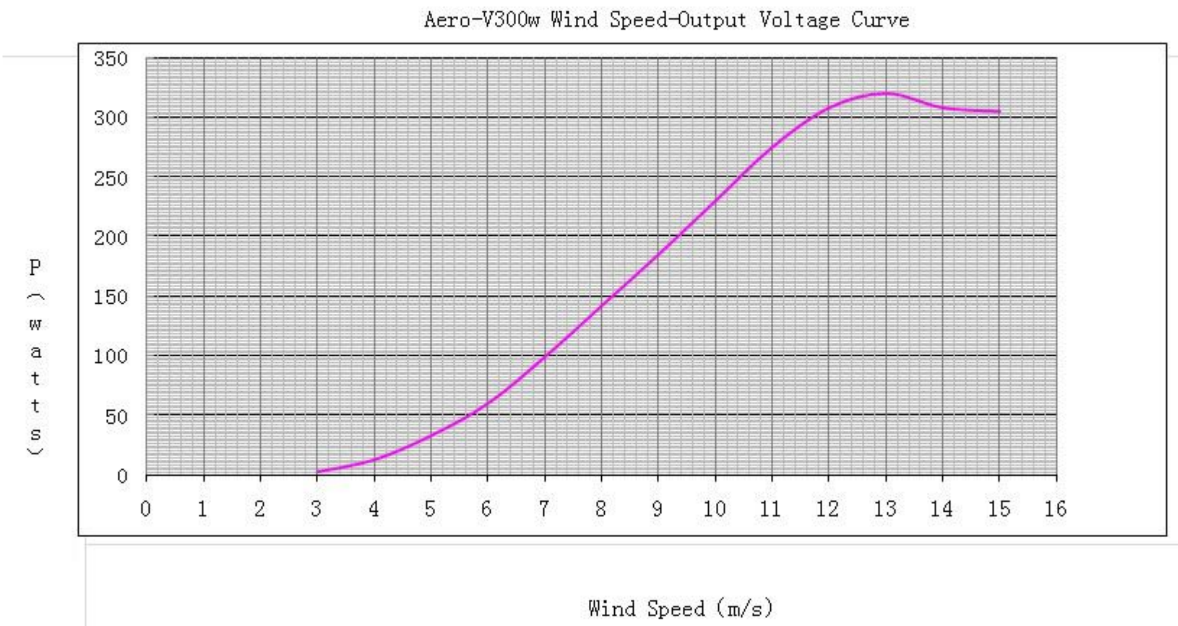
- **Main components:**

1. Rotor shaft or Tower
2. Blades
3. Support structur

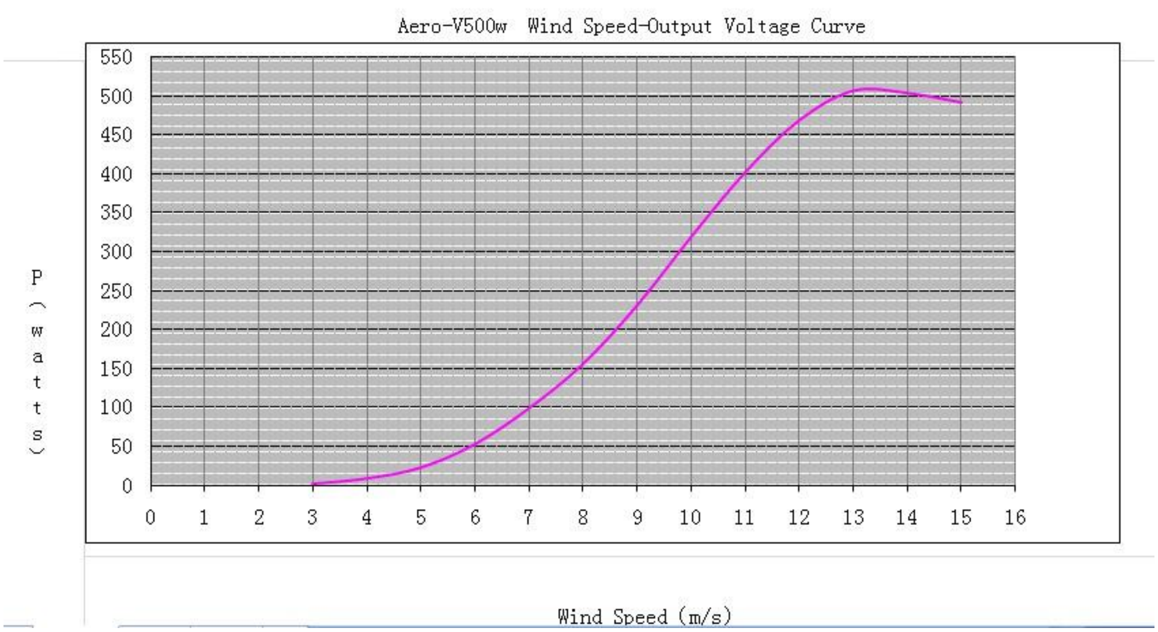
Wind Speed Output Voltage Curve vertical axis wind turbine[Graph 1,2,3]



Graph 1



Graph 2



Graph 3

Comparison dates for wind speed and power output for small wind turbines.[Table 1,2].

Comparison dates for wind speed and power outpurt for 3KW horizontal wind turbine wind speed from 4 to 14m/S										
S.No	**Months**	**Wind velocity in m/s**	**Power Output in W/hr**	**Power W per day**	**Power W per month**	**Price savings per month/Turbine in peso**	**Number of turbine**	**Total price savings by wind energy in peso(example)**	**Price of consumption of grid power for signages in peso(example)**	**Percentage of savings**
1	Jan	4	240	5760	178560	1785.6	1	1785.6	12276	14.55%
2	Feb	5	470	11280	349680	3496.8	1	3496.8	11088	31.54%
3	Mar	6	520	12480	386880	3868.8	1	3868.8	12276	31.52%
4	Apr	7	800	19200	595200	5952	1	5952	11880	50.10%
5	May	8	1100	26400	818400	8184	1	8184	12276	66.67%
6	Jun	9	1500	36000	1116000	11160	1	11160	11880	93.94%
7	Jul	10	1900	45600	1413600	14136	1	14136	12276	115.15%
8	Aug	11	2400	57600	1785600	17856	1	17856	12276	145.45%
9	Sep	12	3000	72000	2232000	22320	1	22320	11880	187.88%
10	Oct	13	3350	80400	2492400	24924		0	12276	0.00%
11	Nov	14	3400	81600	2529600	25296		0	11880	0.00%
12	Dec			0	0	0		0	12276	0.00%
					13897920			88759.2	144540	61.40%

Table 1

Comparison dates for wind speed and power outpurt for 2KW horizontal wind turbine wind speed from 4 to 12m/S										
S.No	**Months**	**Wind velocity in m/s**	**Power Output in W/hr**	**Power W per day**	**Power W per month**	**Price savings per month/Turbine in peso**	**Number of turbine**	**Total price savings by wind energy in peso(example)**	**Price of consumption of grid power for signages in peso(example)**	**Percentage of savings**
1	Jan	4	220	5280	163680	1636.8	1	1636.8	12276	**13.33%**
2	Feb	5	440	10560	327360	3273.6	1	3273.6	11088	29.52%
3	Mar	6	550	13200	409200	4092	1	4092	12276	33.33%
4	Apr	7	1050	25200	781200	7812	1	7812	11880	65.76%
5	May	8	1550	37200	1153200	11532	1	11532	12276	93.94%
6	Jun	9	1850	44400	1376400	13764	1	13764	11880	115.86%
7	Jul	10	2300	55200	1711200	17112	1	17112	12276	139.39%
8	Aug	11	2180	52320	1621920	16219.2	1	16219.2	12276	132.12%
9	Sep	12	2020	48480	1502880	15028.8	1	15028.8	11880	126.51%
10	Oct			0	0	0		0	12276	0.00%
11	Nov			0	0	0		0	11880	0.00%
12	Dec			0	0	0		0	12276	0.00%
					9047040			90470.4	144540	62.48%

Table 2

Wind potential in coordinates 40.287896, 49.722403 in Garadagh district of Baku city was calculated by Sander partner wind re-analysis program.

###########################

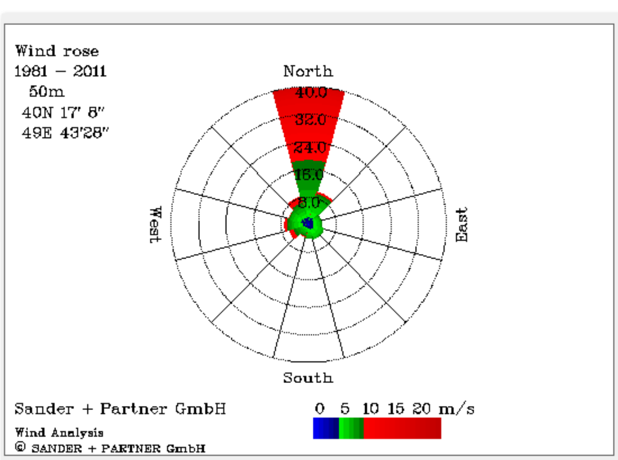
\#   Wind Analysis   #
\#   #
\# www.SANDER-PARTNER.ch #
\##########################
\#

Year	1981 - 2011
Height	50m
Latitude	40N 17' 8" ; 40.286
Longitude	49E 43'28" ; 49.725
A.S.L.	0m

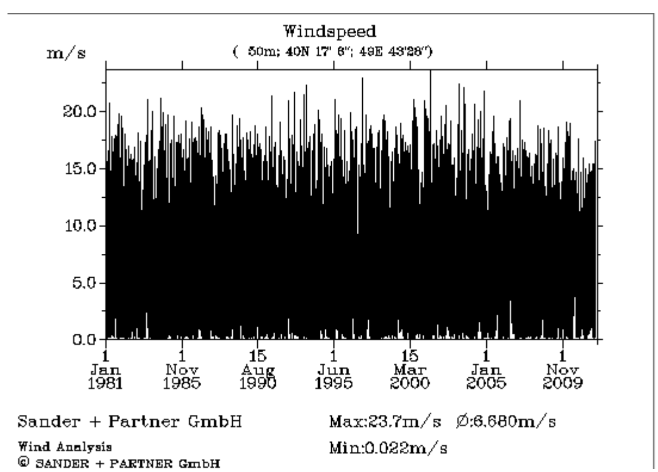
Non-Standard Density

	Windspeed	Windpower	Weibull A	Weibull k
Annual mean	6.68m/s	287.70W/m2	7.54m/s	1.96
January	6.20m/s	219.17W/m2	7.01m/s	2.15
February	6.35m/s	246.52W/m2	7.17m/s	2.04
March	6.15m/s	241.23W/m2	6.93m/s	1.88
April	5.95m/s	221.19W/m2	6.70m/s	1.83
May	5.91m/s	210.01W/m2	6.66m/s	1.86
June	7.48m/s	399.67W/m2	8.44m/s	1.94
July	8.77m/s	513.44W/m2	9.88m/s	2.48
August	8.29m/s	448.21W/m2	9.35m/s	2.38
September	6.84m/s	311.23W/m2	7.71m/s	1.92
October	5.94m/s	207.40W/m2	6.70m/s	1.91
November	6.09m/s	219.62W/m2	6.88m/s	1.99
December	6.15m/s	211.04W/m2	6.95m/s	2.17

We can see wind rose, maximum, minimum and average wind speed at the site. [Graph 4, 5]

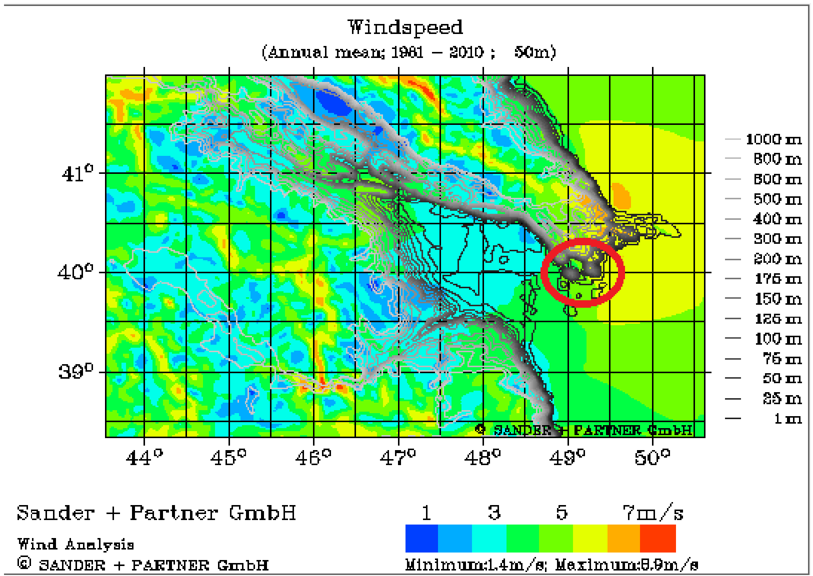


Graph 4.



Graph 5

The following is a wind map of the area. [Graph 6]



Graph 6

Average annual wind indicators in the area. [Table 3]

height m	10	20	30	40	50
Wind speed, m/s	5,41889	5,929858	6,250808	6,489006	6,68

Table 3

Comparison datas for wind speed and power outpurt for 100KW Horizontal wind turbine wind speed from 4 to 15m/S										
S. No	**Months**	**Wind velocity in m/s**	**Power Output in W/hr**	**Power W per day**	**Power W per month**	**Price savings per month/Turbine in peso**	**Number of turbine**	**Total price savings by wind energy in peso(example)**	**Price of consumption of grid power for signages in peso(example)**	**Percentage of savings**
1	Jan	4	4000	96000	2976000	29760	1	29760	12276	242.42%

2	Feb	5	10000	240000	7440000	74400	1	74400	11088	671.00%
3	Mar	6	18000	432000	13392000	133920	1	133920	12276	1090.91%
4	Apr	7	30000	720000	22320000	223200	1	223200	11880	1878.79%
5	May	8	42000	1008000	31248000	312480	1	312480	12276	2545.45%
6	Jun	9	60000	1440000	44640000	446400	1	446400	11880	3757.58%
7	Jul	10	80000	1920000	59520000	595200	1	595200	12276	4848.48%
8	Aug	11	91000	2184000	67704000	677040	1	677040	12276	5515.15%
9	Sep	12	100000	2400000	74400000	744000	1	744000	11880	6262.63%
10	Oct	13	102000	2448000	75888000	758880	1	758880	12276	6181.82%
11	Nov	14	102000	2448000	75888000	758880	1	758880	11880	6387.88%
12	Dec	15	102000	2448000	75888000	758880	1	758880	12276	6181.82%
					551304000			5513040	144540	3796.99%

Table 4

100KW Wind Turbine-Grid-connected System .[Fugure 5, Table 5, Graph 7]

Advantage

Fugure 5

1. **Use ultrasonic wind speed and wind direction meter.** The standard mechanical wind speed and wind direction meter has a simple structure. If the rotating method is used, there will be abrasion loss, which is easy to be worn out by wind and sand, and it is easy to be disturbed by freezing, rain and snow. The use of a brand-new ultrasonic wind speed and wind direction meter, no mechanical friction loss, has a small structure, is not susceptible to external influences, low reliability, and is used to accurately detect real-time wind conditions.

2. **Solar aviation indicator light.** Instead of traditional indicator lights, no external power supply is required, saving installation space. This device is composed of solar panels and multi-layer LED light sources. The high-efficiency solar physical panels provide large-capacity maintenance-free battery storage and provide electrical energy for the flasher to flash at night.

3. **Stainless steel ball lightning rod**. The whole adopts SUS304 stainless steel, which is rust-resistant, beautiful in shape, simple in structure and easy to install. It can be used for direct lightning protection, with wide protection angle and strong wind resistance.

4. **Smart automatic fire extinguishing material integration sticker**. This product is an innovative invention in the fire protection industry and is a simple and highly reliable independent automatic fire extinguishing device. There is no need for any power supply, no special smoke and temperature controllers, no responsible equipment and pipelines, just stick to the inside of the equipment, it can accurately and effectively detect and extinguish the fire source, and kill the disaster in the initial stage.

5. **Automatic greaser.** Instead of the traditional step of manually adding butter to the bearing, it is automatically controlled by the program to add butter to the bearing parts on time and accurately。

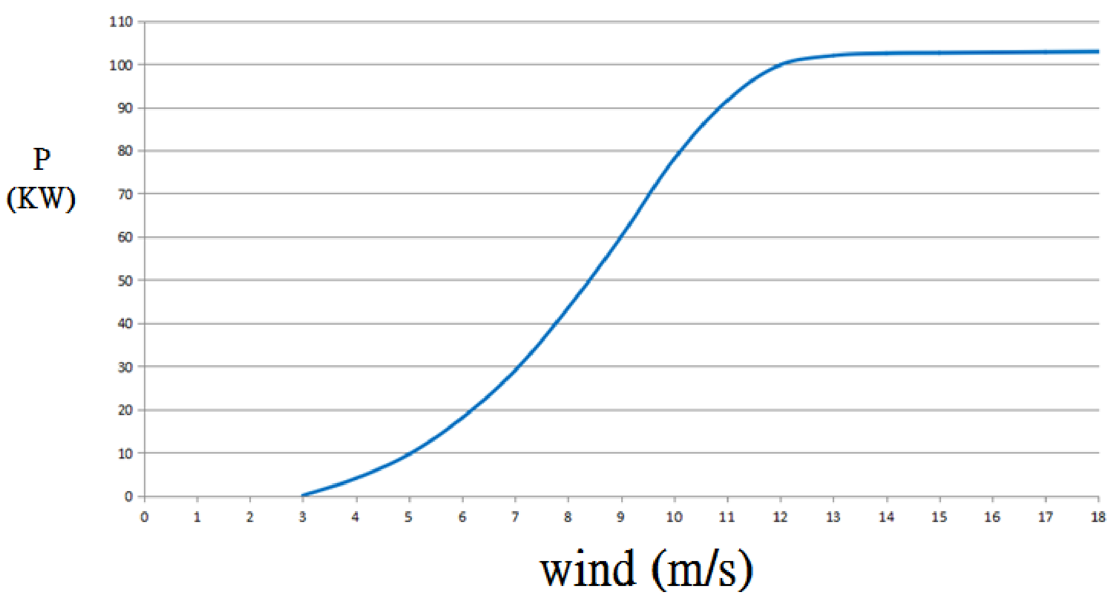
2. Main Space parts of the 100kW wind turbine [Table 5]

ModelNumber	CDD-100k
Ratedpower	100kW
Maxpower	110kW
RatedVoltage	380V

Start up windspeed	2.5 m/s
Rated wind speed	12m/s
Safe wind speed	45m/s
Windwheel diameter	23m
Number of blades	3Blade
Blade material	GFRP
Generator type	PMG
Magneticsteel material	NdFeB
Generator shellmaterial	alloy steel
Brakingmethod	Electronically controlled yawprotection
Wind directionadjustment	Electronicallycontrolled yawandupwind
Operatingtemperature	-40^{0}C～80^{0}C
Lubricationmethod	Addlubricatingoil
Operatingtemperature	-40^{0}C～80^{0}C

Table 5

3. Power Curve of the 100kW wind turbine [Graph 7]



Graph 7

Technical specification some of the small wind turbines.

Model	AERO V500W 	AERO V1KW-IN 
Rated power	500W	1KW
Maximum power	520W	1.1KW
Nominal voltage	12V or 24V	48V or 96V
Flange	DN125	DN125
Rotating	260 rpm	260 rpm
Start-up wind speed	≦ 2.5 m/s	≦ 3 m/s
Rated wind speed	11 m/s	13 m/s
Survival wind speed	40 m/s	40 m/s
Blade hight	0.9 m	2.4 m
Wind wheel diameter	0.6 m	1.7 m
Blades number	3	3 or 4 or 5 (Option)
Blade material	Glass fiber	Aluminum
Generator	Three-phase permanent magnet ac synchronous disc generator	Three-phase permanent magnet ac synchronous disc axis generator
Magnet	NdFeB	NdFeB
Generator case	Aluminum alloy	Aluminum alloy
Controller system	Electromagnetic / brake (Option)	Electromagnetic / brake (Option)
Grid tie	(Option)	(Option)
Battery	Or LiFePO4 PACK (Option)	Or LiFePO4 PACK (Option)
Working temperature	-40°C~80°C	-40°C~80°C
Certification	-	-
Weight	24 kg	220 kg
Packing	1200*260*260 mm	1160*420*470mm & 2250*330*320mm 2 boxes/set
Warranty	1 year	1 year

Table 6

1. Low start up speed; high wind energy utilization; beautiful appearance; low vibration
2. Human friendly design, easy installation, maintenance and repair.
3. Precise injection molding blades together with the optimized design of aerodynamic contour and structure, the blades have such advantages: high utilization of wind energy which contributes to the annual energy output.
4. The generators, adopting patented permanent magnet rotor alternator， with a special kid of stator design, efficiently decrease resistance torque. Meanwhile, it makes the wind turbines match the generators quite well and increase its reliability.

Model：FD3.6-2000. [Figure 6]

1. Blades（3 pieces）
2. Blades hub（1 piece）
3. 3- Nose cone（1 piece）
4. 4- Generator（1 piece）
5. Swing mechanism（1 piece)
6. Tail rod（1 piece）
7. Tail vane（2 pieces）
8. Guyed wire（4 pieces）
9. Guyed cable tower（3 sections）
10. Tower base and other accessories（1 set）
11. Controller（1 piece）
12. Inverter (1 piece)
13. Cable from generator to controller (14m)

Figure 6

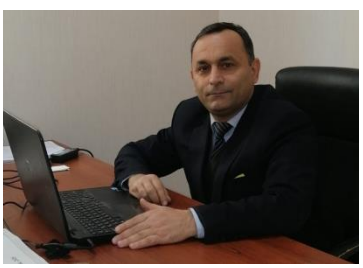
Parameter	
Rated power(W)	2000
Rated voltage(V)	120
Rotor diameter(m)	3.2
Start-up wind speed(m/s)	2
Rated wind speed(m/s)	9
Security wind speed(m/s)	35
Rated Rotating speed(RPM)	400
Blades No.	3
Guyed cable tower height(m)	9
Suggested battery capacity	12V200AH * 10
Matched inverter type	Single-phase Sine wave inverter
Matched cable (m)	20

Conclusion. It can be installed in any area where there is wind. It is especially recommended for use in the Caspian region.[Figure 7, 8]. Wind and Solar energy can be use together. Easy to install in street light systems, water pumps and smart irrigation systems, greenhouse systems, on-grid and off-grid energy supply systems.

Figure 7

Figure 8

The material used in this article is based on the technical advice of Smart Energy Corporation. (https://smartenergycorp.weebly.com/)
Ammonit Mesurement GmbH web site: https://www.ammonit.com/en/



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THE IMPACT OF RENEWABLE ENERGY ON THE ENERGY SYSTEM

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Abstract: the article discusses the impact of renewable energy on the grid. The parameters of power quality are given. The problems of renewable energy sources systems are presented - network integration: wind energy system, solar energy system. Indications of various solutions for the use of renewable energy sources. As a result, end-user devices arebecoming increasingly sensitive to power quality. The latest trends in the system of generation and distribution of electricity are established, showing that the penetration rate of distributed generation into the network has increasedsignificantly and which leads to stabilization of the quality of electricity.
Key words: renewable energy, network integration, power quality, wind energy system, solar energy system.

BƏRPA OLAN ENERJİ MƏNBƏLƏRİNİN ENERJİ SİSTEMİNƏ TƏSİRİ

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Xülasə: Məqalədə bərpa olunan enerji mənbələrinin enerji sisteminə təsiri araşdırılır. Enerji keyfiyyətinin parametrləri verilmişdir. Bərpa olunan enerji mənbələri sistemlərinin problemləri təqdim olunur - şəbəkəyə inteqrasiya: külək enerjisi sistemi, günəş enerjisi sistemi. Bərpa olunan enerji mənbələrindən istifadə üçün müxtəlif həllər göstərilir. Nəticədə, son istifadəçi cihazları enerji keyfiyyətinə getdikcə daha həssas olur. Elektrik enerjisinin istehsalı və paylanması sistemində ən son tendensiyalar müəyyən edilmişdir ki, bu da paylanmış generasiyanın şəbəkəyə daxil olma səviyyəsinin əhəmiyyətli dərəcədə artdığını və elektrik enerjisinin keyfiyyətinin sabitləşməsinə gətirib çıxardığını göstərir.
Açar sözlər: bərpa olunan enerji, şəbəkə inteqrasiyası, enerji keyfiyyəti, külək enerjisi sistemi, günəş enerjisi sistemi.

ВЛИЯНИЕ ВОЗОБНОВЛЯЕМЫХ ИСТОЧНИКОВ ЭНЕРГИИНА ЭНЕРГОСИСТЕМУ

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Аннотация: в статье рассматривается влияние возобновляемых источников энергии на энергосистему. Приведены параметры качества электроэнергии. Представлены проблемы возобновляемых систем источников энергии - интеграция в сеть: ветровая энергетическая система, солнечная энергетическая система. Показаны различные решения по использованию

возобновляемых источников энергии. В результате приборы конечного пользователя становятся все более чувствительными к качеству электроэнергии. Установлены последние тенденции в системе выработки и распределения электроэнергии, показывающие, что уровень проникновения распределенной генерации в сеть значительно возрос и что приводит к стабилизации качества электроэнергии.

Ключевые слова: возобновляемая энергетика, сетевая интеграция, качество электроэнергии, ветроэнергетическая система, солнечная энергетическая система.

In recent years, global energy production and consumption have accelerated to an unprecedented degree. Today's growing demand for electricity, energy crises due to the lack of traditional sources and their impact on the environment are some of the reasons for paying more attention to renewable energy sources, such as wind and solar energy, offer alternative energy sources that generally do not pollute the environment, technologically efficient, environmentally sustainable and provide stable electricity without causing carbon dioxide emissions. However, most of the existing electrical networks, consisting of transmission and distribution networks, are unable to cope with the excess penetration of renewable energy [1].

To meet the growing demand for electricity, the energy sector, along with traditional sources for generating electricity, uses several types of renewable energy sources such as wind power, photovoltaic power, wave power, tidal power, etc. Renewable energy production is unpredictable and intermittent. Therefore, the integration of renewable energy into the energy system without compromising the quality of electricity is not an easy task.

Power quality is a term used to describe how closely the electricity supplied to customers meets the relevant standards to meet the requirements of the end user's equipment. A degradation in power quality is defined as any power problem that manifests itself in voltage, current and / or frequency fluctuations that result in failure and / or malfunction of end-user equipment.

In a traditional electrical network, the causes of poor power quality are variable or non-linear loads such as starting / stopping large motor loads, arc furnaces, lighting, switching devices, traction drives, etc., as well as power failures due to network aging. problems with power lines, insulators, etc. Due to the high penetration rate of renewable energy such as wind, solar energy into the distribution network, which is intermittent or unpredictable, there are additional factors that reduce the quality of electricity.

1. Power quality parameters

The power quality in the distribution network is affected by various types of generator-side and load-side disturbances that alter the performance of the power supply. Power supply parameters such as voltage and frequency must be constantly monitored. Variations in voltage, frequency and noise level will result in a degraded power quality. Here are some of the main parameters of power quality:

1. A voltage drop is a short-term phenomenon in the power system in which the voltage decreases from 10 to 90 percent of the rated voltage at the supply frequency, over a period of 0.5 cycle to 1 minute.

2. Harmonic distortion - Voltage and current harmonics and sub-harmonics are caused by various types of non-linear loads such as arc furnaces, welders, rectifiers, switching power supplies, data processing equipment, etc.

3. Voltage surges - a very rapid increase in voltage within a few microseconds to a few milliseconds. Voltage surges are caused by lightning, switching capacitors and disconnecting heavy

loads. It can sometimes damage electronic components, insulating materials and cause electromagnetic interference.

4. Voltage interruptions are conditions where the voltage at the power terminals is close to zero. By definition, close to zero means less than 10 percent of its nominal value. Power interruptions can be short-term (from a few milliseconds to one or two seconds) or long-term (more than one or two seconds). They usually arise from the actuation or failure of protective devices.

5. Voltage imbalance in a three-phase system means that the values of the three voltages are different, and the phase difference between them is not equal to 120 degrees. This is due to an unbalanced load in a three-phase system.

6. Frequency deviation is a change in a relatively small value of frequency around its nominal value. The power frequency is one of the most important parameters of the power system. Controlling the power frequency is one of the most complex responsibilities of the power system.

7. Power factor: The power factor of a load is defined as the ratio of the average power to the apparent power. With a non-sinusoidal supply, the power factor is affected by current harmonics. The harmonic filter uses suitable capacitors to improve the power factor. The main technical problem is related to the variability of wind and solar energy, which affects the load, generation balance, changing demand for reactive power and voltage stability [2].

2. Challenges of renewable energy source systems - grid integration

2.1. Wind power system.

Due to the abundant availability of wind potential, wind power generation is increasing with the aim of developing rural electrification. But there are some limitations to the penetration of wind energy into the grid. Wind speed forecasting has high uncertainty, high volatility and low predictability, which reduces the safety of the system.

Most wind turbines are not capable of supporting the reactive power in the system. High penetration of wind energy creates stability problems and possible power outages. The frequency behavior of the system also changes with wind penetration due to the lower inertia of the wind turbines. Wind penetration reduces overall efficiency and power quality.

It was revealed that the errors of the horizontal wind shear (downwind direction) affect the power (torque) of the turbine, and the effects of vertical wind shear in the shadow of the tower affect voltage fluctuations.

From a design standpoint, some generators are directly connected to the grid via a dedicated transformer, while others are powered via power electronics to improve controllability and operating range. A review of the literature on new grid codes adopted for the task of integrating large amounts of wind energy into an electrical grid shows that new wind farms must be able to provide voltage and reactive power management, frequency control and troubleshooting in order to maintain the stability of electrical systems. With this in mind, wind turbines with fixed speed induction generators should be phased out as they cannot provide the required voltage or frequency control. A review of the designed controllers for a grid-connected system inverter shows that dual feed induction generators are currently the most efficient design for reactive power control and yaw rate control to maximize output power efficiency. These generators can also support the system during voltage dips. However, the disadvantages of systems based on converters are harmonic distortions introduced into the system [3]. Let us begin saying that any conventional power plant offering energy to the electrical system is compelled to deliver this energy when it is required, and without altering either the stability or the power quality of the system. In short, availability and a certain degree of control on the supplied energy are demanded. It must be said that, at the present time, none of these basic requirements is

compulsory in the operation of plants with renewable energy so- urce, since they are considered to be "small" plants of "distributed" generation. Nowadays, in most countries, wind farms connected to the grid fall in this category.

In this respect, it is necessary to consider that the speed governor of these wind genera- tion systems can be programmed to run the sys- tem under the most suitable operating point in order to control the active power production at every instant regardless of the wind conditions. In some way, this contributes to the primary power-frequency control of the electrical system, insofar as wind conditions allow it.

2.1. Solar power system.

A significant amount of solar energy is available on earth. Customers are interested in solar energy because of the environmental friendliness, flexible installation and the lack of reactive energy consumption by the solar panel.

But there are limitations to solar generation: the high cost of installing solar panels, low generation power, uncertainty in solar radiation and power fluctuations due to the intermittent behavior of sunlight. Solar penetration also changes the voltage profile and frequency response of the system. The PV system is designed with a power factor of unity, and the output power characteristics are dependent on the inverter. Since the photovoltaic system has no inertia, additional devices are required to maintain the frequency in the system.

The photovoltaic system provides active power to the system and does not consume reactive power. [4] studied cloud transient effects when FPs were deployed as a centralized station and found that the maximum allowable FP penetration at the system level was approximately 5%, with the limit imposed by the power-up rate capabilities of conventional generators.

When considering voltage regulation issues, it was found that when clouds pass over an area with high PV penetration levels, when the PVs were distributed over a wide area, at 15% penetration levels, cloud transients cause significant but solvable problems with power fluctuations in the power system. Thus, it can be assumed that 15% is the maximum level of penetration of distributed PV systems into the power system.

PV-based power generation systems have essentially a different nature compared to conventional synchronous generators. PV-based units have stochastic behaviors under various conditions without inertia and dynamic behavior of this kind of generators is subjected by the features and control methodologies used for their power converter parts [3]. Under normal conditions, PV generation has a positive effect on power system behavior. However, in some conditions like cloudy environments and fault contingencies, if the total size of a PV system is large enough, frequency problems may arise at the interconnected power systems. Until now, FACTS controller or PSS, static VAR Compensators and STATCOMs are proposed to improve the power system behavior which may not be always economic [2]. It is worth mentioning that the location, degree of penetration and the manner of dispatching the existing conventional generators have a considerable effect and based on these factors the PV plants may have beneficial or detrimental effects on the system. In some cases with adverse effect of PVs, it is recommendable to keep the critical synchronous generators in service, as well as the SVCs for adequate damping of low frequency oscillations. Alternative power generation sources like P, have a great potential for damping the oscillations in a large power system. Even a single PV-based generating system located at the weakest bus of the grid can still enhance the system loading margins. The damping can be introduced through the high power converters that used as interfaces to the network. Essentially, the AC generation units which are coupled with gas turbines must operate the electric power at a synchronous frequency. Moreover, in the distributed generators,

the power electronic interfaces must act as a frequency changer as well, that change the DC power (for example, in PV) to the utility standard of 60 or 50 Hz. Bidirectional control and unidirectional control are known as two general methods for the PV contribution on active power/frequency services (Figure 1).

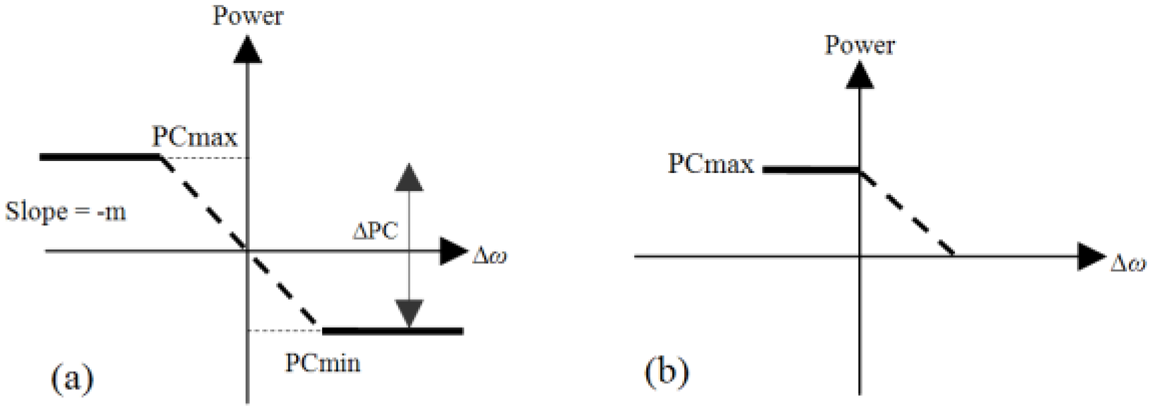

Figure 1. Power control for DGs: (a) Bidirectional; (b) Unidirectional.

In the bidirectional method, plant installations and various energy storage technologies will be required to act as a reserve most of the time. However, in unidirectional method, the DG will be acting only in under or over frequency conditions. For example, in the unidirectional method with DGs that just works in its maximum power output, they can contribute in over-frequency conditions by reducing their output power. Applying a coordinated advanced control for PV system in automatic generation control (AGC) will lead to an interesting research field in load-frequency control services. AGC or load frequency control (LFC) is essential in power system stability and control analysis. The main goal of the AGC is to eliminate any mismatches between generators and load demand and its concepts are well-known. With the increasing trend in displacing the conventional power plants with renewable plants, effects in frequency control will come into sight. Applying various intelligent control methods like fuzzy, neural network and observer methods will be useful for more flexibility [1].

Determination of such values for the penetration of renewable energy sources into the energy system of Azerbaijan is an urgent task for further scientific research.

3. Various solutions for the use of renewable energy

The growing number of renewable energy sources and distributed generators require new strategies for operating and managing the electrical grid in order to maintain or even improve the reliability and quality of the power supply. Renewable energy sources such as solar energy, wind, etc. accelerated the transition to greener energy sources. Considering the above, some of the key decisions for using RES are:

1. The power balance with the use of RES is performed by integrating RES with an energy storage. The advantage of this system is that it allows the integration of renewable energy sources both at the level of distribution networks and in the energy system using the electricity and capacity market.

2. Leveraging power electronics technology, which plays an important role in distributed generation and the integration of renewable energy into the grid, and is rapidly expanding as these applications become more integrated with grid systems. Power electronics has undergone rapid development over the past few years due to two factors: the development of fast semiconductor switches capable of fast switching and increasing their power, and the introduction of real-time

computer controllers that can implement advanced and complex control algorithms. These factors have led to the development of economical and grid-friendly inverters.

3. The effect of intermittent renewable energy generation, which can be mitigated by distributing renewable energy generation to larger geographic areas with small capacities instead of large units concentrated in one area.

4. If there is irrigation load, it is better to supply power at night or during off-peak periods, which is provided by the traditional network. On the other hand, the energy generated by renewable energy sources, for example, solar photovoltaic plants, is generated during the daytime, so developers can use this energy for irrigation purposes instead of storing energy for use at a later time, which increases the cost of the entire system. The use of solar water pumps for irrigation gives high efficiency, about 80 to 90%, and the cost of pumping water with a solar water pump is much less than that of an asynchronous motor pump.

5. In the application of large solar photovoltaic plants, the output power fluctuates throughout the day, and this power is fed into the grid. Continuously fluctuating power raises concerns about network security (in terms of grid resilience). The solar PV plant owner has to install a storage system, which will of course add additional costs to the plant owner. Even when the storage system is fully charged, these storage elements do not generate any profit for the system owner. Therefore, instead of such a storage system, it is more expedient to install a pumping system based on solar energy [5]. An alternative way is to create an installation of storage devices on a parity basis, dividing the costs for them between the owner of the solar station and the power system, for example, equally.

Distributed power systems (DPS) are devoted to customer load supply, which are geographically distributed in an inherent manner, by using distributed generators and energy storage systems spread among distribution networks. Power processing capabilities offered by power electronics have opened new possibilities in the control of DG, which allows implementing ancillary services oriented to compensate the drawbacks of conventional generation units and to improve the dynamic performance of the electrical grid. Among the benefits endorsing DPS, it can be highlighted in their capability to:

- Decrease the weaknesses of the electrical power grid.
- Support sufficient standby generation for improving the system reliability.
- Enhance the regulation mechanism and also for stability of the conventional power grid.
- Decrease the environmental impact of power generation.
- Offset the costs of properties of new transmission system schemes.

It is also worth mentioning here that DPS reduce transmission power losses, as well as the length and total number of transmission lines which have to be built. From the point of view of controllability, DPS allow drawing more flexible and adaptable power systems.

As a result of the analysis of the impact of renewable energy sources on the power system, the following conclusions were drawn:

1. End-user appliances are becoming more and more sensitive to power quality.

2. Recent trends in the power generation and distribution system show that the penetration rate of distributed generation into the grid has increased significantly, which leads to a change in power quality.

3. This article provides an overview of the causes of power quality problems associated with a renewable energy distribution system (wind power, solar power).

It is shown that the influence of the penetration of wind and solar energy is different in nature: with the penetration of wind, the voltage level decreases, with the penetration of solar energy, it

increases.

4. The article presents some of the problems available in the literature related to the integration of renewable energy sources into energy systems:

- to minimize voltage and frequency fluctuations, the use of the latest power electronic devices is a viable option;
- to reduce power fluctuations in photovoltaic systems, energy storage should be used, as well as the use of a pumping load.

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